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Proceedings of the

RELIABILITY OF GLOBAL UNDERSEA CABLE COMMUNICATIONS INFRASTRUCTURE

STUDY & GLOBAL SUMMIT

ROGUCCI

THE REPORT

KARL FREDERICK RAUSCHER

Dubai International Financial Centre
DIFC

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Porthcurno
telegraph museum

Eastern House
Porthcurno
Penzance
TR19 6JX
Tel: 01736 810478
Fax: 01736 810640
Email: libby.buckley@porthcurno.org.uk

February 2010

ROGUCCI Global Summit, DUBAI 2009
Historical Note

There are only a few moments in history that capture a key turning point. Not just a decisive moment for an industry or technology but a shift to a greater awareness of our global communities' dependence on a hidden infrastructure. The ROGUCCI Global Summit in the autumn of 2009 will turn out to be such an event.

Porthcurno Telegraph Museum seized the opportunity to capture this event for future generations, to allow them to look back and review the details of a time when world class experts, stakeholders and champions of international policy change came together to share research after a yearlong study. We have submitted into our archives a time capsule of the summit- including presentations, photographs and audio recordings which will be closed for 30 years but held for posterity.

Signed

Libby Buckley MA Hons., MA, AMA
Director

This document was prepared by:

Karl Frederick Rauscher
Principal Author, ROGUCCI Study Final Report, and General Chairman, Global Summit
Chief Technology Officer and Distinguished Fellow, EastWest Institute
Bell Labs Fellow
Founder & President, Wireless Emergency Response Team (WERT)
Chair Emeritus, IEEE Communications Quality & Reliability (CQR) Advisory Board

The ROGUCCI Study and Global Summit Report has been prepared
under the auspices of the IEEE Communications Society . . .

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Preface

*This Report submits twelve bold Recommendations to the private sector, nation-state governments and other stakeholders for the purpose of promoting the reliability, resilience, robustness and security of the global interconnectivity that underpins modern society – the world's undersea communications infrastructure. These Recommendations are **effective, achievable,** and **urgent**.*

The urgency is driven by the vital role that global electronic connectivity has in the world's economy, society and security. Without reliable international communications services, public welfare is endangered, economic stability is at risk, other critical sectors are exposed, and nation-state security is threatened. The implementation of The Report's Recommendations will significantly reduce these and other risks.

These Recommendations are achievable, yet challenging. Each will require skill, resolve and genuine partnership among government entities and the private sector. Stakeholders have already demonstrated acceptance of this challenge with overwhelming support for The Recommendations during the ROGUCCI Global Summit and by a number of the government and private sector stakeholders volunteering to work on moving the implementation of several recommendations forward. For each Recommendation, The Report presents a concise background context, a discussion of alternative approaches and their consequences, next steps to continue the momentum that has been established during the ROGUCCI process, and measures to gauge progress.

Supporting the twelve recommendations, The Study documents 100 Key Observations. In addition, a major milestone accomplished during The Study was the confirmation of a comprehensive list of intrinsic vulnerabilities of undersea communications cable infrastructure using the Eight Ingredient (8i) Framework for Information and Communications Technology (ICT) Infrastructure. In order to provide more information and updates on follow-up related to The ROGUCCI Study, the IEEE Communications Society has established a web site (www.ieee-rogucci.org).

The world's future communications networks promise to usher in a new world of business and lifestyle-enhancing capabilities. Many of the benefits have not yet even been imagined. The people of all continents and islands stand to greatly benefit from the anticipated economic efficiency, citizen connectivity, functional flexibility, and speed. The Study strongly urges nation-states, the private sector and stakeholders to chart and embark on a new course of policy and practice that demonstrably supports highly reliable, highly resilient, and highly robust global undersea communications cable infrastructure.

Karl F. Rauscher

KARL FREDERICK RAUSCHER
Principal Author, ROGUCCI Report
General Chairman, ROGUCCI Global Summit
CTO & Distinguished Fellow, EastWest Institute
Bell Labs Fellow

The Report is dedicated to

the engineers, scientists, entrepreneurs and seamen

who have served as visionaries, pioneers and laborers
to make the world's undersea cable infrastructure
what it is today.

Modern society is profoundly unaware
of its debt to their service.

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WASHINGTON, D. C. 20551

STEPHEN R. MALPHRUS
STAFF DIRECTOR FOR MANAGEMENT

DATE 26 October, 2009

TO ROGUCCI Study Contributors

On behalf of financial sector stakeholders around the world, I want to express my deep appreciation for the diligence embodied by the ROGUCCI study team. As leaders around the world strive to create meaningful public-private partnerships, this effort stands out as a role model of private-sector initiative that is addressing one of the world's most vital needs – highly reliable global electronic infrastructure.

The important role that global communications networks play in modern society can not be overstressed. Whether it be the operation of day to day businesses, the wide range of investment activity, or countless real-time transactions – each of these requires global communications services that are highly available and resilient. In addition, the financial sector is becoming increasingly global and its stability more contingent on its understanding and effective management of its operational risk. The quote I have coined a while back to capture the reality of this dependence says it best: "When communications networks go down, the financial services sector does *not* 'grind to a halt', rather it *snaps* to a halt."

I have been fortunate to be a part of the IEEE community over the years – most notably the Committee on Communications Quality & Reliability, who is actively involved in the ROGUCCI work. As technical and professional excellence is a hallmark of this community, I look forward with high expectations for the impact of this study.

Sincerely,

Stephen R. Malphrus

KOREA COMMUNICATIONS COMMISSION

20 Sejongno, Chongno-go, Seoul 110-777, Korea URL : http://www.kcc.go.kr

20 October, 2009

TO: Attendees of the ROGUCCI Global Summit

As the President-Elect of the IEEE Communications Society (ComSoc), I want to thank you for your commitment to strengthening the world's communications networks. While Korea is often cited as one of the most advanced countries in terms of technology deployment, we know that there are no borders in cyberspace and we are all only as strong as the weakest link. Robust undersea communications cable infrastructure is vital to every part of the world, as future economic development will increasing be dependent on information and communications technology. In recent years, several earthquake-caused cable outages in this part of the world have revealed the nontrivial disturbance that loss of global connectivity can have throughout the world

I, together with Doug Zuckerman, the President of ComSoc, applaud my fellow IEEE leaders for their vision in summoning their peers and having the foresight to include stakeholders from the financial sector and international policy change agents. This was a bold step, but a necessary one. The "netizens" of the world that do not have our expertise would expect that such vigilance as is being displayed here would be taking place.

Best Wishes for a successful Global Summit! I look forward to reading the proceedings.

Byeong Gi Lee

Byeong Gi Lee
President-Elect, IEEE Communications Society
Commissioner, Korea Communications Commission

cc: Doug Zuckerman, the President of the IEEE Communications Society

EASTWEST INSTITUTE
Forging Collective Action for a Safer and Better World

April 20, 2010

Surprisingly few people understand that the entire global economy relies on the uninterrupted usage of the vast undersea cable communications infrastructure. Yet some 99% of all intercontinental digital traffic worldwide is carried by these cables. The EastWest Institute is proud to be the global policy partner with the IEEE's worldwide community of technical experts in addressing this neglected yet essential issue. It is quite remarkable that policy elites and those responsible for the functioning of the global economy have not yet addressed head on the vulnerabilities of the GUCCI system—the Global Undersea Cable Communications Infrastructure—and what can be done to build resilience into the system.

The four-day ROGUCCI Summit in Dubai sponsored by IEEE and EWI in cooperation with the Dubai International Financial Centre was a mind opener. I witnessed both the industry's mastery of this complex international communications subject and the diligence of the private sector stakeholders striving to take their risk management to the next level. The countless individuals and organizations that are vitally dependent upon this infrastructure - but simultaneously quite unaware of it - would have been pleased with the energy and commitment of the individuals who have devoted themselves to this cause, and taking care of their interests.

The role of global undersea communications cable infrastructure is now an essential part of global stability and modern civilization. This ROGUCCI Report presents clear recommendations for private sector, governments and stakeholders that are needed now to protect and promote its resilience. Their implementation will require vision, cooperation and collective action from committed individuals in many nation-states. While others who are part of the ROGUCCI process bring competencies of science, engineering and commerce, the EastWest Institute has committed to champion at the policy and governance level, international agreements that will make a difference.

The EastWest Institute is now finishing its third decade of serving as an agent for breakthroughs that promote global peace and human welfare. We see in our common global cyber fabric both an enabler for unprecedented civil advancement and prosperity, but sadly, also as an accelerant for instability, should we experience its catastrophic failure. Thus the reliable electronic connectivity of the continents must be an increasing priority for nation-state leaders of today's world. The EastWest Institute owes an inestimable gratitude to our EWI Distinguished Fellow Karl Rauscher, who has had the vision, tenacity, professionalism and open-mindedness to seek out the best possible global team to produce such a quality study. Our job is to assure its recommendations are acted upon and that the opportunity for catastrophic failure is severely reduced.

Sincerely,

John Edwin Mroz
President and Founder

BRUSSELS • MOSCOW • NEW YORK

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1. EXECUTIVE SUMMARY

The Reliability of Global Undersea Communications Cable Infrastructure (ROGUCCI) Report presents twelve Recommendations to the private sector, nation-state governments and other stakeholders. These Recommendations, if implemented, will significantly enhance the availability, resilience, reliability and robustness of the world's international communications infrastructure. This guidance is based on broad international stakeholder perspectives, international technical policy development experience, expertise in emerging technologies and the insights captured in The Study's 100 Key Observations. Summary statistics of the ROGUCCI Study are as follows:

6	**Continents represented**
12	**Recommendations articulated** (Section 5)
57	**Trends affecting infrastructure reliability** (Section 3)
79	**Intrinsic vulnerabilities considered** (Section 3)
100	**Key Observations** (Section 4)
300+	**Contributing international stakeholder experts** (Section 2)
10,000+	**Distinct data points researched and analyzed during study**
30,000,000,000,000+	**Bits *per second* traversing Global Undersea Communications Cable Infrastructure (GUCCI)**

Both developing and established nation-states understand the vital role of modern information and communications technology (ICT) in providing security and stability, stimulating economic growth, enhancing education, and fostering the expression and advancement of culture and society. However, this ICT infrastructure is sharply devalued if it is not connected to the rest of the world. Nation-states in every part of the globe have a critical need for continuous, reliable and secure international connectivity. To strive for highly dependable international communications capabilities is to face enormous technological, economic and political challenges.

To be clear, today's undersea communications cables have provided a reliable service that is very dependable. The service is the result of heroic technological breakthroughs and corresponding diligence in building and operating these vast links that span our planet. Certainly, for the most part, the countless government agencies, businesses and individuals who rely on the Internet, global supply chains and modern financial markets everyday have been able to enjoy the luxury of grossly under appreciating the contributions of this industry to modern society.

However, the insatiable thirst for bandwidth is accompanied by an ever-growing dependence on inter-continental communications, which are nearly entirely supported by undersea cables. Given this exploding dependence by seemingly all aspects of society, the question quite naturally emerges: *Is the level of reliability of this critical international infrastructure keeping pace?* It was the value offered by mastery of the answer to this question that first motivated the ROGUCCI Study.

The consequences of the loss of international communications have proven to be severe. Indeed several large-scale outages have occurred in recent years that have had an unacceptable impact for those affected (see Appendix A, Appendix C). It has been observed that never before in human history has mankind so quickly embraced – and become so completely reliant upon – new technology, as this current generation.[1] And it must be quickly followed with the observation that it is not clear whether civilization can emerge without irreversible consequences from the widespread catastrophic failure of such technology.[2] Given the utter dependence, recent history of failure, and the reality of latent failure modes, the imperative for The Study could not be more urgent.

For a nation-state, or other stakeholder such as the financial sector, to simply keep pace with the accelerating advances of the information and communications industry it must meet many challenges. However, for a nation-state or stakeholder to ensure highly available and highly robust global communications, it must do more – including cooperate with international partners with the same goals. The twelve Recommendations presented in The Report prescribe critical areas that should receive priority attention to achieve this objective. Because many of these issues are common across many stakeholders, **international cooperation** and **private sector-government cooperation** are repeated themes throughout The Report.

Other key messages in The Report are the following:

There exists a **profound lack of awareness** by the general public, businesses and governments regarding their daily dependence on global undersea communications cable infrastructure.

There appears to be a gap between the growing dependence on international bandwidth and the reliability of its underpinning infrastructure at a *global level*. This is not so much that the reliability of the systems is any less, but that the dependence has grown so great. The industry is keeping up with the insatiable thirst for bandwidth with heroic advances in technology and deployment of new systems. However, investment to ensure the resilience at *a global level* is outside the scope of those building this increasingly critical international infrastructure.

There is **no sufficient alternative back-up** in the case of catastrophic loss of regional or global connectivity. Satellites cannot handle the volume of traffic – the available capacity is not even close.

Guiding Principles of The Study

Several principles guided the approach taken in The Study. First, the **interests of the citizens** of world were at the forefront. For this reason, there is an emphasis on the importance that global interconnectivity plays on the welfare of societies around the world.

[1] Kissinger, Henry, *Does America Need a Foreign Policy?,* 2002.
[2] 52% of EWI Worldwide Security Conference 7 – Cybersecurity Consultation participants indicated that "the loss of global connectivity for an extended period of time (e.g., more than a month) would be catastrophic for global society, with irreversible consequences." Brussels, February 2010.

Second, The Study was to be **forward-looking** in terms of the future needs of society, businesses and governments. Therefore, The Study factored in numerous trends, such as regional economic growth hotbeds, skyrocketing bandwidth demand, the shift of network control from being "silicon"-based (hardware) to being software-based, the emerging capability to provision bandwidth dynamically, ocean sprawl, increased piracy activity on the high seas, growing concerns of terrorist activity worldwide, and the disappearance of national network boundaries as a result of global interconnectivity.

Another principle was to use a **worldwide spotlight**. To manage discussions of this novel perspective, a new term (GUCCI) is introduced to refer to the 'global undersea communications cable infrastructure.' In addition to this focus, an appropriate awareness of nation-state sovereignty was maintained as a consideration for the private sector operation and ownership of individual international cable systems.

Including all of the various **regional insights** that were offered was another principle on which The Study was based. This was accomplished throughout the methodology described below by seeking and then carefully considering input received from extensive outreach conducted via diverse means.

Yet another principle was to ensure **rich representation of industry, academic and government** perspectives, with care to include both long-established companies as well as new entrants. Thus, a wide variety of service providers, network operators and equipment suppliers were engaged. Government perspectives were gleaned from both regulator and stakeholder agencies. The Study also obtained input from other critical sectors that depend on the communications sector.

Finally, the approach utilized **world-class proficiency** in both the technical subject matter and broader policy areas to ensure the resulting guidance would be both realistic and achievable. The Study utilized only individuals of the highest caliber of demonstrated competency. For example, in the unique technical policy development arena, the small core leadership team included individuals whose high recommendation implementation rate is a matter of public record. Further, the subject matter expertise of the technical community included subject areas central to The Study: network reliability and security, infrastructure protection, nation-state security, emergency preparedness, disaster recovery, emergency communications, ad hoc emergency networks, hardware and software quality and government-industry collaboration.

Methodology of Study

The methodology used in The Study was designed to support data gathering, validation and analysis with the aim of developing meaningful guidance. There are several distinguishing characteristics of The Study's methodology. First, The Study employed a **framework of the complete list of ingredients** that make up undersea communications cable infrastructure: power, environment, hardware, software, payload, network, human and policy. The striking advantage of using this framework is that it readily lends itself to the **comprehensive listing of intrinsic vulnerabilities**, which are finite – unlike threats, which, for practical purposes, are infinite. Present-day security approaches are for the most part founded on the threat side of the equation, which is derived from historic experience and gathered intelligence. In contrast, the intrinsic vulnerability approach, rooted in a detailed knowledge of the ingredients that make up a communications network, permits profoundly higher degrees of confidence in terms of ensuring reliability and robustness. This focus on vulnerability analysis does not exclude the use of threat analysis, which draws extensively on observed trends and the subjective perspectives of individuals. Rather, it uses that knowledge and supplements it with expert knowledge about the systems that make up communications networks.

Secondly, The Study was heavily dependent on the expertise and experience of a **unique formula of individuals**. Specifically, technical and operational experts, government and financial sector stakeholders, and international policy change agents were integrated throughout the ROGUCCI process. Experts from all facets of the communications industry were sought out and engaged. Thousands of years of experience are represented in the contributions made. It is worth noting that the dimension of experience that was drawn upon is not solely restricted to years of experience, but breadth of experience as well. Experts with limited years in the industry but with new and unique perspectives were included in The Study. Future networks will be a collection of a diverse set of components – analyzing them requires a diverse set of perspectives.

Next, the findings of The Study were facilitated with a **wide range of approaches**, including extensive literature research, face-to-face interviews, Internet forums, conference calls and a Global Summit.

Finally, the **three step process** of a Study, Global Summit and then Report development and dispatch played a key role in maintaining focus on the objective of actual improvement of the infrastructure's reliability. This process facilitated the development of twelve Recommendations that are actionable and effective.

In summary, the methodology used throughout The Study is based on proven approaches for similar highly consequential advisory undertakings regarding critical infrastructures.[3] The framework, range of experience and expertise, personal interaction and recommendation process enabled a deep dive into the issues facing the world's electronic connectivity, drew upon the knowledge of those most familiar with it, and established a model for future cooperation and sharing.

The 100 Key Observations

100 Key Observations have been identified relative to the reliability and robustness of global undersea cable infrastructure. These observations are a combination of information offered by experts in interviews and derived determinations from analysis of the aggregated information. With unique analysis points on the order of 10,000, there were certainly more observations that could be made. Those selected were deemed essential for appreciating The Recommendations that were formed. In a sense, the Key Observations form a foundation for The Report's Recommendations.

[3] U.S. President's National Security Telecommunications Advisory Committee (NSTAC) Next Generation Networks (NGN) Task Force, 2006.

The Key Observations are presented in four broad categories: Stakeholder, Science & Engineering, Business & Investment, and Government & Inter-Government. An example for each of these areas is provided below. Note that each Observation is accompanied with a color code that signals which of the eight infrastructure ingredients it is tied to.

Stakeholder.

16. **Financial Sector Due Diligence.** Insufficient reliability data is available for financial sector and other stakeholders to support needed risk calculations. In order to do appropriate diligence, stakeholders should be able make statistical predications regarding the expected frequency and duration of outages and the range of impairments (e.g., payload latency) that can affect their operations. However, insufficient data is available to support such analyses.

Science & Engineering.

21. **Rare Glimpse of c's Limit**. Usually the speed of light makes communications appear instantaneous for humans. However, long haul undersea cable systems provide a rare human experience with the finite nature of the speed of light on the earth. A trip encompassing the circumference of the earth requires approximately one tenth of a second – a delay noticeable to a human. During cable failure alternate routes that require routing over longer distances is common, resulting in latency that is unacceptable for some real-time sensitive applications.[4]

Business & Investment.

74. **Specialized Cable Ships**. Cable ships and their crews are typically shared resources. Contention for such limited resources is one of the contributing factors in extended duration outages, particularly when multiple cuts are involved.

Government & Inter-Government.

78. **Geo-politics.** Geo-political impediments have limited the implementation of a fundamental sound principle of reliability engineering – avoiding single points of failure.[5]

[4] The speed of light is ~3.0 x10^8 meters/second, which would take 0.13 seconds to travel ~4.0 x 10^7 meters, the circumference of the earth.
[5] Examples include the cable-dense Luzon Strait, Strait of Malacca and Red Sea passages.

The 12 ROGUCCI Recommendations

Summarized below are the ROGUCCI Study's Twelve Recommendations for improving the reliability, robustness, resilience and security of the world's undersea communications cable infrastructure. In this executive summary, each Recommendation is presented with an abbreviated context, consisting of a brief introduction to the issue, a purpose statement and summary of the commitments required by the private sector and governments and other stakeholders. An anonymous quote collected from a Study contributor is used to introduce each recommendation.

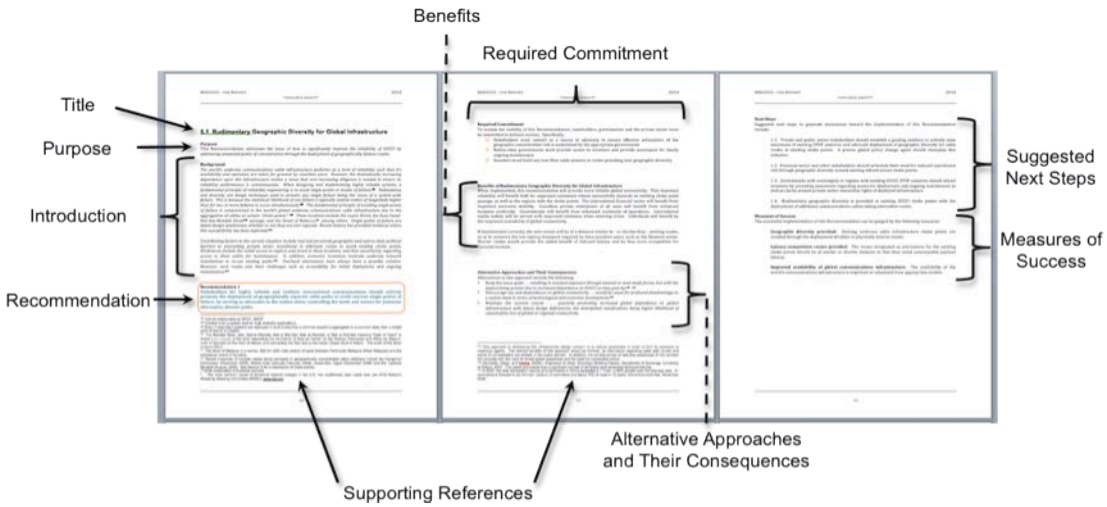


Figure 1. Presentation of Recommendations in Section 5

Each Recommendation is supported with a mixture of the Key Observations, knowledge and experience of the vast expertise engaged, and validation by industry peers and stakeholders. Each Recommendation is presented in Section 5 with a more complete context – yet in a concise format (Figure 1).

Table 1. ROGUCCI Recommendation List

	ROGUCCI Recommendations
1	Rudimentary Geographic Diversity for Global Infrastructure
2	Prioritization for Timely Cable Repairs
3	Preparedness for Hostile Maritime Crisis
4	Best Practices and Trusted Information Sharing
5	New International Governance
6	International Communications Infrastructure Standard for the Financial Sector
7	Measurements for Stakeholder Due Diligence
8	Improved Cable Protection Agreements, Standards, Policies and Regulations
9	Government Inter-Agency Coordination for Undersea Cable Infrastructure
10	Education and Awareness of Critical Role of Undersea Communications Infrastructure
11	Mechanisms for Handling Overload Demand
12	Recognize GUCCI Catastrophic Loss as a Grand Challenge

1. Rudimentary Geographic Diversity for Cable Infrastructure

"I've been in the industry for almost 30 years and always wondered who is worrying about this . . . in the early years I remember telling my wife . . . but we all seem to accept it. But one day our hoping may run out."

Issue

At a global level, the overall interconnectivity of the continents violates a fundamental reliability design principle – *avoid single points of failure*. There are several geopolitical chokepoints that funnel these critical cable paths together. A single disaster in such an area could cause catastrophic loss of regional and global connectivity.

Purpose

The Recommendation addresses the issue of *how to significantly improve the reliability of GUCCI by addressing unwanted points of concentration through the deployment of geographically diverse routes.*

Recommendation

Stakeholders for highly reliable and resilient international communications should actively promote the deployment of geographically separate cable paths to avoid current single points of failure, by serving as advocates to the nation-states controlling the lands and waters for potential alternative, diverse paths.

Required Commitment

The effective implementation of The Recommendation requires the commitments of stakeholders, governments, the private sector and an effective international policy change agent. Stakeholders must commit to a course of advocacy to ensure the appropriate governments understand the geographic concentration risk. Nation-state governments must provide access to investors and provide assurances for timely ongoing maintenance. Finally, investors must build out new fiber cable systems in routes providing new geographic diversity.

2. Prioritization for Timely Cable Repairs

"There is no excuse for this . . . and they are hurting the businesses and citizens of their own country as much as anyone."

Issue

Bureaucracy of nation-states with territorial water sovereignty too often causes extensive delays in the restoral of service over damaged undersea communications cables. Repair times are already long. These delays extend the approval portion from days to weeks or even months.

Purpose
The Recommendation addresses the issue of *how to significantly reduce the average time needed to restore service after cable damage by addressing the lengthy approval process for cable repair vessels to gain access to sovereign waters.*

Recommendation
Nation-state governments should implement policies and procedures to provide timely approval to authorized cable ships seeking permission to repair damaged undersea communications cables.

Required Commitment
The effective implementation of The Recommendation requires the commitments of governments and the private sector. Nation-state governments must conduct advance planning in anticipation of cable damage, and elevate the priority restoration of undersea communications cables. They must also provide an efficient and appropriately speedy process for granting authorized repair vessels access to their sovereign waters, and be willing to compare themselves to best-in-class benchmarks for timely issuing of permits. Cable ship operators and cable infrastructure owners must cooperate with government requirements for information, onboard inspections, escorts and other requests, particularly when opportunities for pro-active engagement are presented.

3. Preparedness for Hostile Maritime Crises

"Can you imagine? Pirates in this day and age!"

Issue
Increased hostile activity around the world requires the undersea communications cable industry to enhance its preparedness for attacks on its specialized cable ships and critical infrastructure. In addition to the obvious danger to lives and property, such activity could cause long-term service outages.

Purpose
The Recommendation addresses the issue of *how to provide a mechanism for rapid response to hostile activities against international communications cables or the industry's specialized cable ships by undertaking coordination, planning and other emergency preparedness activities.*

Recommendation
Nation-state governments should cooperate with each other and private sector undersea communications cable infrastructure owners and operators to develop maritime crisis preparedness plans that would protect communications cable vessels that are vital to the operation of global undersea communications cable infrastructure.

Required Commitment

The effective implementation of The Recommendation requires the commitments of governments and the private sector. Nation-state governments must cooperate in establishing intergovernmental agreements, participating in planning, and being part of periodic simulated crisis exercises. Owners of cable ships must support effective planning and exercises by making vessels and critical personnel available. Finally, nation-state governments and cable ship owners must establish cooperative procedures for maritime crisis response.

4. Best Practices and Trusted Information Sharing

"The Summit made it clear there are real opportunities for improved cooperation."

Issue

With the enormous challenge of protecting and advancing the reliability of GUCCI, there are compelling reasons for ensuring that industry peers are well informed, as better awareness can be critical in optimizing strategies for protection and reliability assurance. This information sharing is needed on an international basis, as inter-continental undersea cables are by definition *international* critical infrastructure.

Purpose

The Recommendation addresses the need to share sensitive information among industry and government stakeholders, within a trusted environment, enabling all participants to benefit from this shared body of knowledge that is essential to optimize network reliability and resilience.

Recommendation

The private sector should establish formal means for sharing information that can improve the protection and rapid restoration of undersea communications cable infrastructure.

Required Commitment

The effective implementation of The Recommendation requires the commitment of the private sector and nation-state governments. Private sector companies that own and operate undersea communications infrastructure must jointly establish a trusted environment for sharing information to improve the protection and rapid restoration of GUCCI. The private sector must be willing to share threat and outage information within a trusted environment within the industry for the common good. Nation-state governments must be willing to share threat and other sensitive information with owners and operators of GUCCI and safeguard information provided by the industry. Nation-state governments must be willing to share information that will improve the protection and rapid restoration of critical infrastructure with other nation-states as well as the owners and operators of that infrastructure within the other nation-states.

5. New International Governance

"We still have time for private sector leadership here . . . we can avoid inefficient and costly government oversight if we better organize ourselves and cooperate better."

Issue

The Report establishes the need for dealing with individual undersea cable systems as an aggregate, i.e. global level. The need is based on the limited focus of commercial interests that manage individual systems, the difficulty stakeholders have in performing due diligence in managing their operational risk and the extremely high level of importance that this infrastructure plays in the world. Some groups are re-examining their charters to determine how they might address some of the new or more critical issues of the nature discussed at ROGUCCI Summit. Observations from financial sector stakeholders were that the undersea communications industry would benefit from a "system-wide" view, more inclusive participation in industry collaborative programs, more structured governance, better coordination and a unified voice. Specific mission areas for new governance would ideally include defining expectations for the industry, engaging representative stakeholders and articulating agreements, standards, policies and regulations (ASPR) that would advance GUCCI resilience.

The implementation of Recommendation 4 is complimentary to this Recommendation. Both of these Recommendations in turn support Recommendation 7.

Purpose

The Recommendation addresses the issue of how the undersea communications cable industry supports the needs of its stakeholders in providing the information they need to manage their dependence on GUCCI.

Recommendation

The private sector should establish a new international governance framework for global undersea communications cable infrastructure to provide optimum support for its resilience through cross-sector coordination and effectively support stakeholder interests.

Required Commitment

The effective implementation of The Recommendation requires the commitment of the private sector and stakeholders. Stakeholders must maintain a proactive posture in engaging this critical international infrastructure partner. Existing industry fora must evaluate their charters, membership and commitments in light of the stakeholder and internal industry needs. Existing industry fora must, as appropriate, be either willing to make charter and membership representation adjustments, or be supportive of sister organizations playing new complimentary roles. Private sector companies must provide expert and leadership resources to champion new governance functions.

6. International Communications Infrastructure Standard for the Financial Sector

"We are completely dependent on this. We don't have any other way."

Issue

The world's international undersea communications cable infrastructure continues to operate at highly reliable levels and continues to provide tremendous service to the financial services sector. Recommendations 4 and 7 position the communications industry to better share information and provide needed information to the financial sector, respectively. Correspondingly, this Recommendation calls on the financial sector to better define its needs and expectations, and to develop a structure to organize operational risk guidance that allows both providers and users to manage their growing global dependency on GUCCI.

The implementation of Recommendations 6 and 7 work from the two sides of the same problem.

Purpose

The Recommendation addresses the issue of how the financial sector should manage its dependence on GUCCI, specifically in the context of an overall improved management program for its dependence on information and communications technology in general. While one sector is the focus in The Recommendation, it should be viewed as representative of all international critical sectors.

Recommendation

The international financial sector should introduce a new core standard for its information and communications technology dependence that will include guidance on assuring institutional resilience and managing the operational risk associated with undersea communications cable infrastructure.

Required Commitment

The effective implementation of The Recommendation requires the commitment of the international financial sector, international undersea communications cable industry and world's economic leaders. The international financial sector must recognize GUCCI reliability as a strategic priority for the stability of its operations. The international financial institutions must commit operational risk managers to developing the details of global guidelines. The financial sector and international communications industry must commit to a partnership to develop a core standard that both can agree on. The financial sector members must voluntarily implement the developed core standard. The world's international financial authorities must utilize these standards in their determination of ratings and other stability-related decisions.

7. Measurements for Stakeholder Due Diligence

"We can do better . . . it is clear those counting on us need this."

Issue

As the financial services sector continues to evolve on a global basis, increased reliance on information and communications technology (ICT) translates directly into increased reliance on undersea cable infrastructure. Today's global markets are vitally dependent on resilient international connectivity. Major gains achieved in reducing market risk through such mechanisms as automation and compressed settlement intervals are offset by increased operational risks through increased dependencies on ICT in general, and undersea cable infrastructure specifically. Those responsible for overseeing their institution's exposure to operational risk cannot perform due diligence because there is insufficient information available. The fundamental information that is needed centers around statistically based expectation of downtime for international connectivity. There is basic lack of published, or otherwise available, information on GUCCI reliability for stakeholders that play critical roles in societies around the world.

The implementation of Recommendations 4 and 5 will create structure and spirit to enable this Recommendation to succeed. Further, Recommendation 6 will be enabled by the implementation of this Recommendation.

Purpose

The Recommendation addresses the issue of how the undersea communications cable industry supports the needs of its stakeholders by providing the information they need to manage their dependence on it.

Recommendation

The private sector should establish a method of providing basic reliability performance statistics to stakeholders.

Required Commitment

The effective implementation of The Recommendation requires the commitment of the international undersea communications cable industry. Stakeholders must maintain a proactive posture in engaging critical international infrastructure partners. Private sector companies must be willing to share the outage information needed to support overall GUCCI performance measurements, with appropriate non-disclosure agreement protections. Existing industry fora must evaluate their charters, membership and commitments in light of the stakeholder and internal industry needs. Existing industry fora must, as appropriate, be either willing to make charter and membership representation adjustments, or be supportive of sister organizations playing new complimentary roles. Private sector companies must provide expert and leadership resources to champion new governance functions.

8. Improve Cable Protection Agreements, Standards, Policies and Regulations

"If we could just get all of the best policies from around world packaged together, we could say, 'Look! Here is what you can do.' "

Issue

The protection of undersea cables in international law is well established, dating back to the 1880s. Cable protection laws have been updated with new policy at the international level. However, too often there is not corresponding nation-state-level policy to match the importance established at the international level. This is of particular concern because undersea communications cables are especially vulnerable in the transition from deep water to their landing site. As a result, avoidable cable damage is routinely experienced.

Purpose

The Recommendation addresses the issue of how to provide better protection of deployed cable systems using available or new policy instruments.

Recommendation

Nation-state governments should implement best practices for protecting undersea communications cables within their sovereign waters.

Required Commitment

The effective implementation of The Recommendation requires the commitment primarily of nation-state governments, but with important support of the private sector. Nation-state governments must make the protection of undersea communications cable infrastructure a priority. The private sector must assist the government in understanding the types of damage experienced. Governments must be able to improve their protection through effective policies and practices.

9. Government Inter-Agency Coordination for Undersea Cable Infrastructure

"I know it seems impossible, but we have to try . . . There is no law of physics that keeps this from being better."

Issue

The undersea cable industry is too often impacted by weak government policies that impede its efforts to improve the reliability of its systems and services. One of the primary causes of this is poor coordination among government agencies. It is understandable that each agency will have its own primary interests. However, this often results in inconsistent policy, confusion and delays. There are no easy solutions. Drawing attention to this problem is a first step, but it must be followed with commitments and actions for improvements to be realized. Some of the opportunities for progress may lie in greater education and awareness among key policy makers and regulators, the quantification of the negative impact of uncoordinated government, the private sector's capture and articulation of the best practices for this area, and public recognition of role model behavior.

Purpose

The Recommendation addresses the issue of how to transform governments' lack of inter-agency coordination when it comes to policy for undersea cable protection.

Recommendation

Nation-state governments and the private sector should establish a best practice model for undersea communications cable inter-agency coordination to ensure consistent policies and practices.

Required Commitment

The effective implementation of The Recommendation requires the commitment primarily of nation-state governments, but with important support of the private sector. Nation-state governments must make oversight of undersea communications cable infrastructure a priority. The private sector must assist government in understanding observed inconsistencies and impact, and provide role model references. Governments must be able to improve their inter-agency coordination to provide consistent policy and speedy implementation.

10. Education and Awareness of GUCCI Critical Role

"It is not only the general public . . . this CEO of a high tech company thought that most international communications were over satellites."

Issue

There is a profound unawareness on the part of the general public, business enterprises, critical sector stakeholders and government regarding their dependence on undersea communications cable infrastructure. While the increasing rate of dependence climbs steeply, there is no corresponding movement in consciousness of the dependence or the risks associated with it

Purpose

The Recommendation addresses the issue of how to close the profound gap between critical dependence and awareness that stakeholders and the general public have regarding GUCCI.

Recommendation

The undersea communications cable industry should begin an outreach campaign that provides appropriate education to government and other stakeholders regarding GUCCI function in the stability of their operations.

Required Commitment

The effective implementation of The Recommendation requires the commitment primarily of private sector, but with important support of stakeholders. The undersea communications cable industry must recognize the unacceptable nature of the existing dependence-unawareness gap, and commit to action to resolve the under-education of its dependents. Stakeholders must be diligent in achieving appropriate levels of knowledge regarding their dependence and develop best management practices regarding their dependence on GUCCI.

11. Mechanisms for Handling Overload Demand

"This is the sort of thing that it is better to plan for and control than the alternative."

Issue

There are several reasons for increased vigilance regarding future infrastructure congestion. An overload condition is a very real scenario, which may present itself intermittently in unexpected fashion, or as a temporary situation due to a specific event. Terrestrial networks have anticipated the need for managing overloads with the deployment of various mechanisms. How can international coordination ensure that the communications most critical for continued government operation and security be maintained?

Purpose

The Recommendation addresses the issue of how to prepare for traffic overload scenarios for the global undersea communications cable infrastructure.

Recommendation

Network operators, service providers and stakeholders should develop and implement agreed upon mechanisms for handling traffic overload conditions for undersea communications cable infrastructure.

Required Commitment

The effective implementation of The Recommendation requires the commitment of nation-state government and the private sector. Nation-state governments must agree that some communications are more important than others and therefore require preferential treatment during times of infrastructure congestion. Nation-state governments must agree with each other on mutual preferential treatment of so-designated traffic. Nation-state governments must provide incentives for private sector development and deployment of priority schemes. Nation-state governments, stakeholders, network operators and service providers must securely manage the administration of authorized priority traffic. Service providers and network operators must implement agreed-upon overload management mechanisms.

12. Recognize GUCCI Catastrophic Loss As a Grand Challenge

"There is no 'Plan B'."

Issue

Nearly 100% of the world's inter-continental electronic communications traffic is carried by the undersea cable infrastructure. Terrestrial based routes alone would leave continents in isolation. The probability of a global or regional failure is very low; however, it is not zero. The impact of such a failure on international security and economic stability could be devastating. It is unclear if civilization can recover to its previous condition from the failure of a technology that has been so rapidly adopted without a back-up plan. Without GUCCI, the world's economic financial market would immediately freeze. But what would happen next? What are the options? What can be done to best prepare for this possible event?

Purpose

The Recommendation addresses the concern of preparing for a large-scale loss of the world's undersea communications cable infrastructure, by directing stakeholders to prepare for the worst case scenario and by calling on the scientific and engineering community to respond to a new grand challenge problem.

Recommendation

Subject Matter Experts and Stakeholders should prepare for the worst-case scenario of a catastrophic loss of global undersea communications infrastructure by identifying best available alternatives and operational procedures. Preparation should include scientific and engineering research for long-term solutions.

Required Commitment

The effective implementation of The Recommendation requires the commitment of governments, stakeholders and the private sector. Governments and other stakeholders must encourage academic and private sector research to ensure appropriate resources are focused on this global challenge. Scientists and engineers must be devoted to developing alternatives. Stakeholders must conduct planning scenarios that consider true worst-case scenarios. The financial services sector can play a lead role in helping establish the importance of this concern.

Summary

This Study submits twelve major Recommendations to the private sector, governments and other stakeholders - especially the financial sector - for the purpose of improving the reliability, robustness, resilience and security of the world's undersea communications cable infrastructure. In practical terms, these twelve Recommendations are offered as challenges to individuals. These will be the ones who will need to make the difference when a difference is called for. The senior leaders and subject matter experts of equipment suppliers, network operators and service providers; the leaders and participants of the industry's fora; researchers; consultants in small firms; government policy makers and staff employees; IT specialists in financial firms; and many others – all are strongly urged to include this Report in their dialogue and to do so speedily, as the improvement opportunities described have important benefits to many throughout the world. Likewise, the consequences have many downsides.

It is encouraging that at the time of this Report dispatch, a number of private sector interests have indicated their willingness to take the next steps suggested for several Recommendations. Each of The Recommendations should be considered and acted upon with urgency proportional to the vital role that international communications networks and services will play in the future. The critical priority for implementation is clear. Without reliable international communications networks and services, public welfare is endangered, economic stability is at risk, other critical sectors are exposed, and nation-state security is threatened. The implementation of this Report's Recommendations will significantly reduce these and other risks. Each of the twelve Recommendations is both challenging and achievable. The intent of the ROGUCCI process from the beginning has been to improve the world's communications. Successful implementation of each Recommendation will significantly improve the reliability and robustness of communications services for the citizens around the world. However, each will require skill, resolve and genuine partnership among government entities, stakeholders and the private sector.

This Study strongly urges the private sector, governments and other stakeholders to chart and embark on a new course of policy and practice that forcefully advocates highly available, highly reliable, highly robust, highly resilient and highly secure international communications infrastructure.

2. INTRODUCTION

The ROGUCCI (ro–goo–che) process objectives, scope and methodologies are presented in this section. This material is essential for understanding the supporting work behind The Report's guidance. It can be used as background and reference material for readers who prefer to focus on The Recommendations in Section 5.

To assist with the discussion of the aggregation of individual undersea cable systems and the concept of a single infrastructure, the term 'GUCCI' (goo–che) is here introduced as an acronym for 'global undersea communications cable infrastructure.'

2.1 Objectives

The objectives of The Study were to:

• examine the *reliability* of undersea communications cable infrastructure at a *global* level,
• assess the potential *impacts* of infrastructure failures–with financial sector focus, and
• provide *guidance* for improved global infrastructure resilience, if needed.

Each of these objectives was achieved as is documented in The Report. The reliability of the infrastructure is reviewed in Section 3, *Analysis of Undersea Communications Infrastructure*, with the Intrinsic Vulnerability approach that not only provides a systematic structure, but also comprehensive coverage. Additional tutorial-level background as well as advanced information is provided in Section 4, *Key Observations*. The impacts of potential failures are discussed throughout and specifically in Appendix C. Section 5, *Recommendations*, provides guidance to the private and public sector for improving the reliability, resilience and robustness of GUCCI.

While The Recommendations cover gaps needing to be addressed at a global infrastructure level, it is important to recognize that there are many aspects of the industry that are highly effective in delivering reliable infrastructure and services. To start, the market forces that shape the primary supply chain interfaces between 'the equipment supplier and network operator,' 'the network operator and the service provider,' and 'the service provider and the end user' have been effective in achieving the current high levels of reliability. These market forces include immediate awareness of outages due to their observability through service impact; competition from alternative service providers, network operators and equipment suppliers; and an improved return on investment for highly reliable systems, networks and services[6] [Figure 2].

[6] Exceptions to this are described in Key Observations 71.

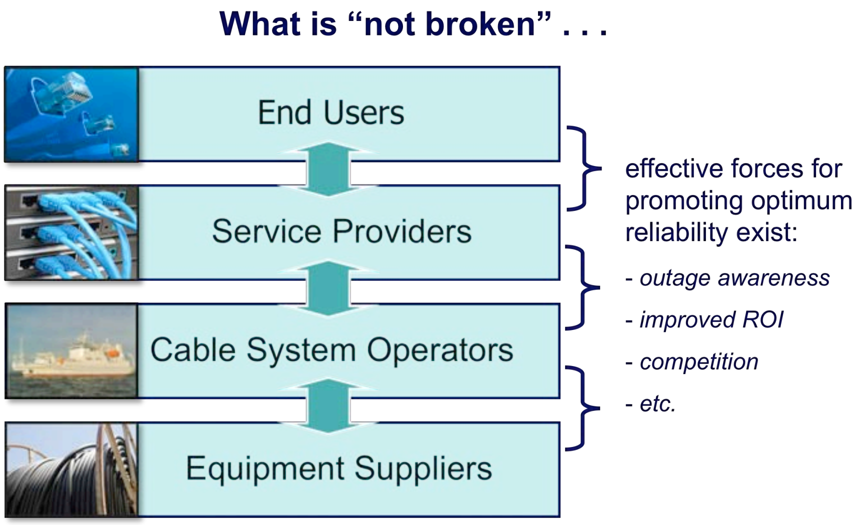


Figure 2. Effective Market Forces

Technology advances as well as healthy commercial relationships have enabled this industry to grow, be trusted, and ultimately become the underpinning of the global economy. The history of GUCCI has witnessed its maturing with time and investments along an "S-curve" to produce resilience at a remarkable level. This achievement is particularly noteworthy given the nature of the challenges faced, such as extreme dimensions of length and depth, harsh environments and gigantic load. However, forces preventing further advances are limiting the current performance level [Figure 3]. These forces involve realms that are outside the industry's core competencies – i.e. engineering, operations, management, legal – and are outside the supplier-operator, operator-provider and provider-user relationships. One such limiting outside force is geopolitical interest. These limiting forces are identified, explored and addressed in The Study.

The dramatic increasing dependency upon GUCCI makes it imperative that these forces be overcome so that correspondingly fresh levels of reliability, resilience and robustness can be achieved [Figure 4]. It is in this way that the ROGUCCI process is complimentary to the many existing activities currently under way that promote the reliability of this infrastructure. The Recommendations presented in The Report, if implemented, will provide breakthroughs to improve reliability. Together they offer a new "S-curve" opportunity that can build upon achievements to date and enable access to higher performance at a global level.

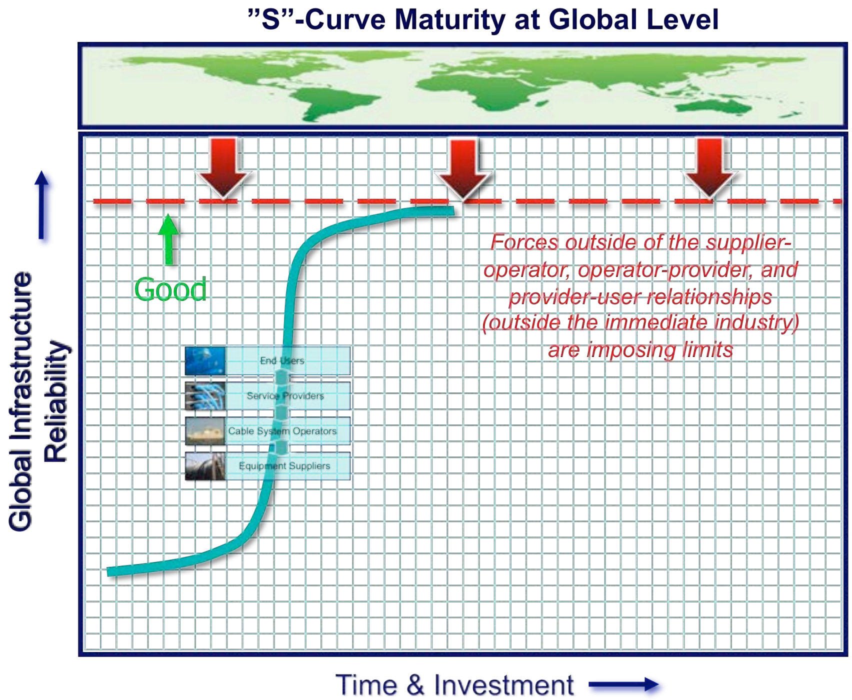


Figure 3. Current "S"-Curve Limitation

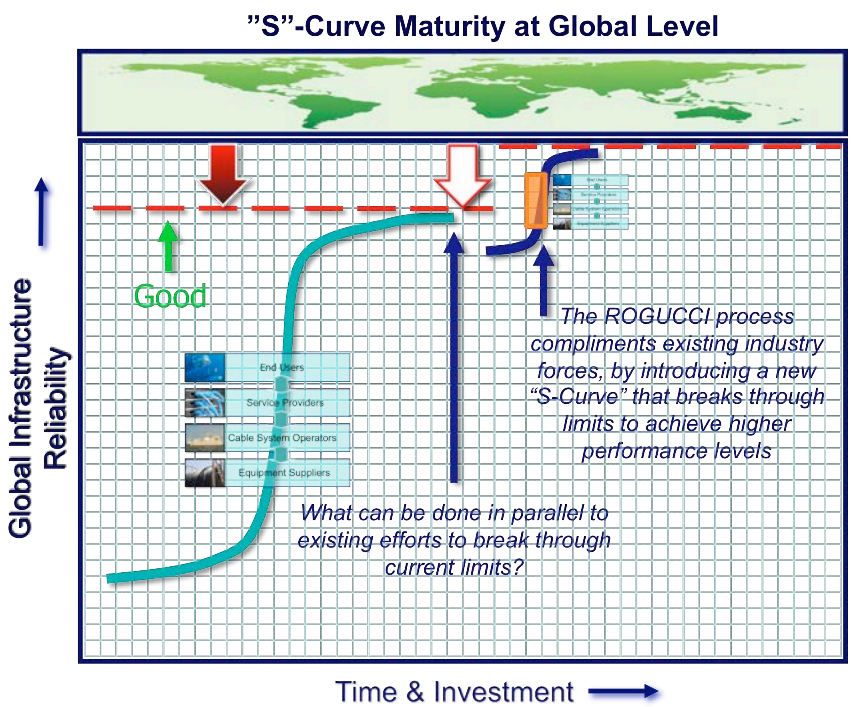


Figure 4. New "S"-Curve Opportunity

2.2 Uniqueness of Approach

The character of the ROGUCCI process is unique in four primary ways.

First, the **focus is at the *global level*.** The first objective was to look holistically at the undersea communications cable infrastructure, i.e. at a global level, as distinguished from a focus on individual undersea communications cable systems, which are often international. The former considers the aggregation of all international systems. This undertaking was significant because most reliability work in this arena is done at the individual system level for specific deployed technology. In this way The Report complements existing mechanisms and forces in play throughout the relationships between equipment suppliers and network operators, between network operators and service providers, and between service providers and customers.

Second, consideration is given to **"*things that can happen, that have not yet*."** This is significant because of the relatively rare frequency of failures within this infrastructure and the ever-increasing dependence upon it. Diligent exploration was made of failure types and modes that are latent within the infrastructure. This was accomplished through a disciplined Intrinsic Vulnerability approach and through comprehensive coverage provided by using the Eight Ingredient (8i) Framework to ensure inclusion of all possible contributors to downtime (Section 3).

A third distinction of the approach is openness to consider and **address areas previously "*untouchable*."** This brought The Study into areas beyond the current discussion of improvement areas. Most notably, The Study addressed constraints imposed by geopolitical perceptions and realities.

A fourth difference in the approach is **the ROGUCCI brain trust "formula."** This formula includes individuals with interests, expertise and experience in three domains:

- technical experts (across 8i for undersea cables, reliability, etc.)
- finance sector and other stakeholders to represent the impact of infrastructure failures
- international policy change agents to affect global policy

The contributions of these "breeds" were authoritative insights into the "what" (i.e. scientific and engineering limitations and parameters), the "why" (i.e. the practical consequences and impacts), and the "how" (i.e., convening, reframing and mobilizing for international policy change), respectively. These are each key elements of the ROGUCCI process.

2.3 Importance of the Subject

The reliability of GUCCI is absolutely essential for the basic functioning of nation-state governments, the stability of critical stakeholders such as the international financial sector, the continued operation of business enterprises and the daily lives of countless individual netizens. For these parties, *their current high level* of dependence, *their rapid rate of increased* dependence and *their enormous expected future* dependence are self-evident motivations for vigilance in improving the resilience of this infrastructure.

Beyond establishing that the subject matter is important, a compelling need for The Study is the profound lack of awareness of these dependencies. Only a small minority in each of the parties above is aware of the nature of their dependence on GUCCI.

The Study was conducted in close partnership with senior leaders of the international financial community. This sector continues to evolve on a global basis with increased reliance on information and communications technology (ICT), and vital dependence on resilient international connectivity. This global connectivity translates directly into increased reliance on undersea cable infrastructure. "Financial services executives and managers must recognize the technical complexity, risks and contractual requirements, ongoing relationships, and recovery challenges associated with the international telecommunications infrastructure".[7] The major gains achieved in reducing market risk through such mechanisms as automation and compressed settlement intervals are *offset by increased operational risks* through increased dependencies on ICT in general, and undersea cable infrastructure, specifically.

Improvements in the reliability of this global infrastructure will benefit international communications users around the world – governments, private sector organizations, and individuals.

2.4 Defining Progress

The above subsections answered the three questions about the ROGUCCI activities: *What is it about? Why is it important?* and, *Who cares if it is successful?* This section will continue this line of thought by answering the question: *What are the measures of success?*

Success for the ROGUCCI process is defined as follows:

1. Raising the *critical stakeholders' awareness* of their vital dependence on GUCCI.

2. Articulating *actionable recommendations*, that, if implemented, would reduce the likelihood, or ameliorate the global impact of, a catastrophic undersea communications cable infrastructure failure.

The Study and Global Summit, which are described in later subsections, have begun to elevate awareness. The engagement of hundreds of experts and stakeholders, the traffic of thousands of ROGUCCI Study web site visits, and the high profile international Summit event have created impetus for fresh discussions. The nature of awareness is important and is being appreciated chiefly in two dimensions: by the depth of understanding and by those who are undertaking the understanding. In the area of depth, greater understanding is being fostered at all stages of the awareness continuum – from the point of initial awareness to advanced appreciation for actionable countermeasures. Those engaged in the understanding are key. Since the private sector is largely the owner of this infrastructure, it is essential that equipment suppliers, service providers and consortium operators are engaged.[8] Owing to the fact that senior level decisions will eventually be needed to implement The Report's guidance, the direct participation of senior government and industry leaders has been welcomed. Inasmuch as this is an international concern, it is encouraging that experts and stakeholders from six continents are actively engaged. The dispatch of The Report is expected to continue this momentum.[9] The ultimate measure of success in this area of awareness is whether enough critical stakeholders develop an accurate sense for their vital dependence on GUCCI.

Regarding the second measure, it is fulfilled in The Report's presentation of twelve actionable recommendations, that, if implemented will improve the reliability of GUCCI (Section 5).

[7] *Resilient International Telecommunications Guidelines for the Financial Service Sector,* Pacine, Wayne and Callahan, Roger, Financial Service Sector Coordinating Council, www.fsscc.org, 2009.
[8] See Section 2.8.
[9] Updates will be provided on www.ieee-rogucci.org.

2.5 Scope

This section describes the scope of The Study in terms of subject matter interests, technology, network types, and geography.

The Report provides an expert review of the reliability of the global undersea communications cable infrastructure. Because there exists abundant material in the public domain that covers the components and architecture of this critical infrastructure, The Report does *not* attempt to duplicate that excellent body of knowledge. Rather, the focus of The Report is on the **factors promoting or impairing the infrastructure's reliability**. The Report provides a **comprehensive analysis of the intrinsic vulnerabilities** of the infrastructure, significant trends affecting these vulnerabilities and **suggested guidance on addressing latent and emerging reliability challenges**. This focus on reliability, in this context, will include the related aspects of infrastructure availability, resilience, robustness, and security.

2.5.1 Subject Matter Interest

The subject matter of interest is reliability in a broadly defined sense. For the broadly intended audience, reliability here is used as an umbrella term to include the general expectation of stakeholders that GUCCI will work for them. As such it includes aspects of the following:

> *Reliability*, in its technical sense, principally that the infrastructure will perform its intended function, in the context of the environment it was designed for, during the lifetime it was designed for.
>
> *Robustness*, principally that the infrastructure will perform its most important functions with a minimum of variation, in the presence of stresses that are outside of its expected operating conditions.
>
> *Resilience*, principally that the infrastructure will return to performing its function after being overcome.

Related terms that overlap the broad contour of Reliability, and that are appropriately kept in front of mind in The Study include:

> *Security*, principally that the infrastructure will be protected.
>
> *Survivability*, principally that the infrastructure will be preserved in some minimum useful state after being overcome.

The brief glossary found in Section 9 provides more detailed descriptions of terms.[10]

Therefore, this broadly defined infrastructure reliability includes the stakeholders' expectations that it will perform (a) '*as intended*' during times absent of unusual stress, (b) '*near as intended*' during times of unanticipated stress, and (c) '*returning to as intended*' after being overcome by stress.

The downtime experienced during and after a crisis contributes to the overall downtime for a specified period of time that a reliability calculation may be desired for.[11] Reliability has two chief accounting

[10] Additional related terms include availability, dependability and integrity.

measuring sticks: the *frequency* of outages and the *duration* of outages. As it more directly correlated with end user "pain", the duration – or "downtime" metric is the single most useful means of describing the performance of a communications system. The highest reliability is achieved when disruptive events are recovered from quickly (*short duration*) and the mean time between disruptive events is very long (*low frequency of events*). Conversely, the lowest reliability is experienced when disruptive events have extended times (*long duration*) and the mean time between disruptive events is very short (*high frequency*).

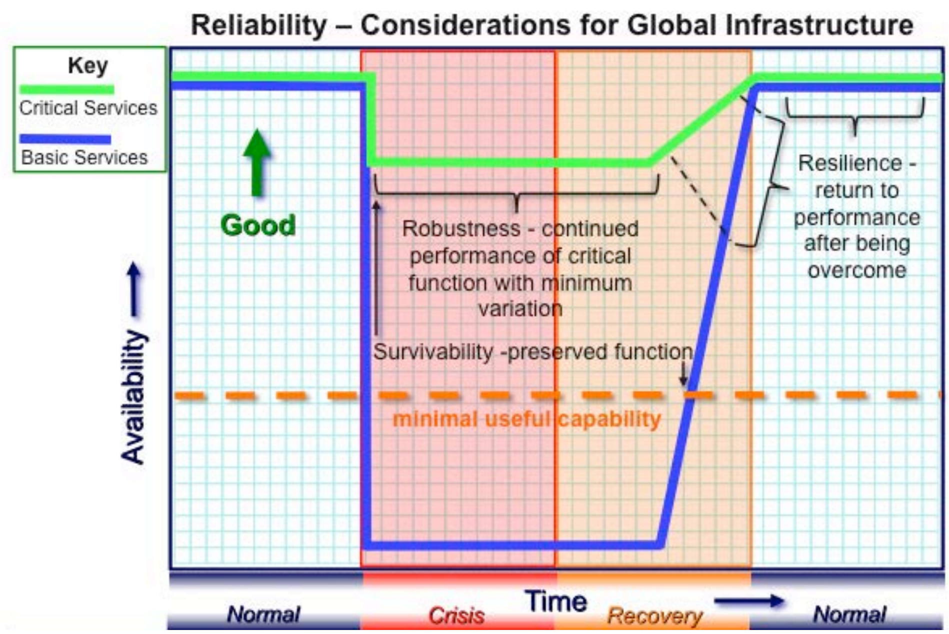


Figure 5. Terms on Time Continuum

The context of use:

- the time period is 24 hours per day, 7 days per week, 365 days per year
- the operating environment includes extremely harsh conditions on the bottom of the ocean floor
- at global level, such events as earthquakes, tsunamis and other catastrophes are expected events

In The Study, the concept of "unanticipated stresses" is different than what may be described in contractual arrangements involving equipment suppliers, network operators and service providers for specific, individual international cable systems. For example, earthquakes may be considered a rare event for an individual system. But at a global level, such rare events are understood to be part of the world we live in, and, given the dependency on GUCCI, something with which it needs to be prepared to operate. Therefore the standard commercial legal arrangements made at an individual system level should not be measured against what is expected by the broad user base, as that is not their intent, nor are they wellsuited for such purpose. From a global infrastructure perspective, earthquakes are not that unusual; nor are malicious acts of terrorists on infrastructure; nor is piracy; nor are cyber attacks.

[11] Because outages or other crises are rare events for GUCCI, long duration periods are needed in order to develop statistically meaningful reliability measurements; i.e. on the order of years when multiple systems are involved.


2010 SUBMARINE CABLE MAP
COPYRIGHT © 2010 TeleGeography ALL RIGHTS RESERVED.
RUSSIAN FEDERATION
MONGOLIA
CHINA
INDIA
PACIFIC OCEAN
CANADA
AUSTRALIA
INDIAN OCEAN

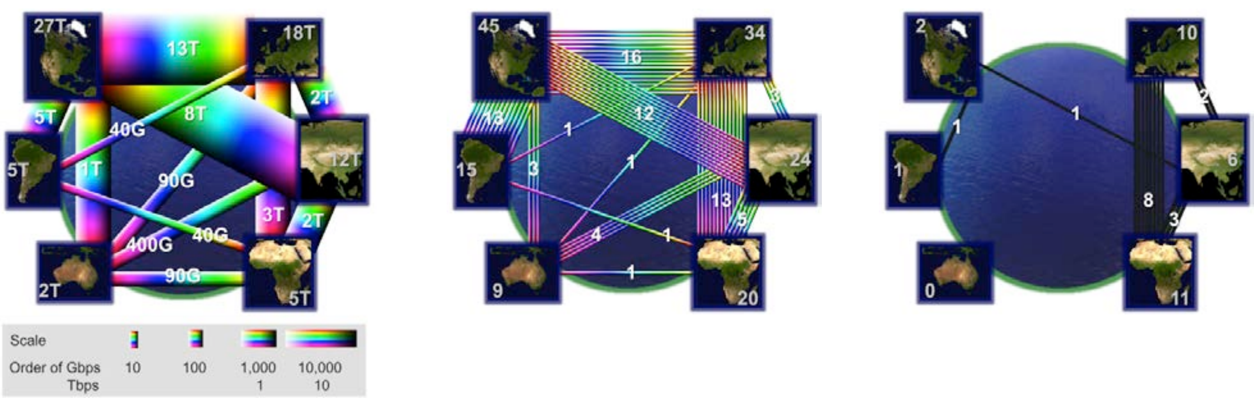

ARCTIC OCEAN
GREENLAND
UNITED STATES
MEXICO
ATLANTIC OCEAN
VENEZUELA
COLOMBIA
PERU
BRAZIL
BOLIVIA
CHILE
ARGENTINA
ALGERIA
LIBYA
EGYPT
MAURITANIA
MALI
NIGER
CHAD
SUDAN
ETHIOPIA
ANGOLA
SOUTH AFRICA
SAUDI ARABIA
KAZAKHSTAN
INDIAN OCEAN

(on previous pages)

Figure 6. Global Map of Submarine Cable Routes[12]

2.5.2 Geography

The scope of The Report is the expanse of the earth. Submarine cables connect six continents, and traverse three oceans and several seas. While there are no currently deployed systems that span the Arctic Ocean, this route is being studied.[13]



(a) (b) (c)

Figure 7. Inter-Continental Connectivity via Undersea Communications Cables
(a) Capacity, (b) Existing Cables, (c) Planned[14]

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[12] Used with Permission from TeleGeography.
[13] Barthold, Jim, *Submarine Cable to Find Northwest Passage*, Suite101.com, 17 January 2010.
[14] Some double counting is included for routes with multiple stops. Middles East included with African Continent in these charts. Data provided by TeleGeography Research, 2010.

2.5.3 Network Types

The scope includes long haul network runs. This excludes short runs such as those underwater cables connecting small islands within a nation and those that cross rivers and lakes within a nation. Though these smaller networks are excluded, value can still be gleaned from The Report for such applications, particularly in the systematic review of intrinsic vulnerabilities (Section 3).

2.5.4 Infrastructure Boundaries

In addition to the cables, repeaters and branching units, the undersea communications cable infrastructure includes the terminations points on land, which consist of some type of building structure, power, and electronic hardware that provides the interface with the terrestrial networks (Figure 8). The infrastructure also includes the specialized equipments and human resources needed for their maintenance – in particular the cable repair ships and their crews.

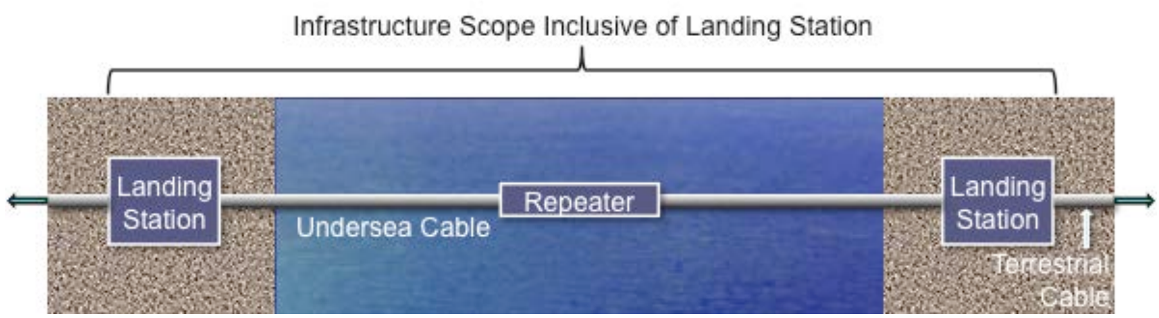

Figure 8. Infrastructure Boundaries

2.5.5 Technology

The scope of The Report covers optical fiber submarine cables. Earlier metallic conductor cables are excluded as those deployed are either no longer used or their bandwidth capacity is negligible in modern networks.

2.6 The Study

The ROGUCCI process was designed with three phases that spanned approximately 2 years. The first phase was The Study that included research, interviews, small meetings, and virtual forums. The next phase was the Global Summit, which convened subject matter experts, stakeholders and international policy change agents. The final phase is The Report preparation and publishing, which includes the dispatch of twelve bold recommendations to improve the reliability of GUCCI. The objectives, unique approach and scope are further detailed in this section.

2.6.1 Research Locations

Locations where research activities were conducted include each of the countries shown in Table 2.

Table 2. Research Locations

Commonwealth of Australia	French Republic	Kingdom of Saudi Arabia
Kingdom of Belgium	Federal Republic of Germany	Slovak Republic
Kingdom of Bahrain	Greece (Hellenic Republic)	United Arab Emirates
Canada	Japan	United Kingdom
Republic of Estonia	People's Republic of China (incl. Hong Kong)	United States of America

2.6.2 IEEE Online Forum

The Study included the use of discussion forums facilitated by the IEEE Communications Society (ComSoc). A ROGUCCI Study online forum was established to facilitate virtual collaboration among experts and stakeholders from around the world without the constraints of time zones, business workweek structure or physical proximity.[15] Individuals offering to contribute to The Study could request membership to the web forum group. The online forum was used to examine the specific intrinsic vulnerabilities of each of the infrastructure's eight ingredients (Section 3), observed trends that can affect the reliability of GUCCI and proposals for recommendations to improve the reliability of GUCCI.

The forum also enabled individuals to post documents for recommended reading. In addition, the discussion forums were used to vet drafts of The Report. The online forum was an experiment in that it was new both for many of the individuals who joined it and as a critical component of a global study and conference (Figure 9). As such, some pioneering was required to navigate through some of the unfamiliarity. As with many online forums, for a given thread, there were typically more observers than contributors. This demonstrated that the forum had gone some way toward the goal of achieving better understanding of GUCCI.

Figure 9. ROGUCCI Online Forum

The forum became an effective nerve center for discussion, the posting of information, and other updates. In fact, the discussion group quickly became one of ComSoc's most popular in its newly developed online forums space - over 100 individuals from 6 continents have joined the online discussion group, and the IEEE ROGUCCI web site has had **over 10,000 visits**.

The ROGUCCI online forum will continue in order to support the implementation and other follow-up activities related to The Recommendations.

[15] http://community.comsoc.org/groups/rogucci-study .

2.7 Global Summit

The ROGUCCI Global Summit was convened to bring together Study contributors and stakeholders as a culmination of their ongoing collaboration to assess the reliability of the undersea communications cable infrastructure at a *global level*, the potential impacts of infrastructure failures – with financial sector focus, and proposed recommendations for improved global infrastructure resilience. This interactive event culminated an eighteen month-long study among experts who have been collaborating virtually around the world.

2.7.1 Venue

Figure 10. The Gate at the DIFC

The Global Summit was hosted by the Dubai International Financial Centre (DIFC), in the United Arab Emirates (Figure 10). Dubai was chosen as The Summit venue because of its prominent role as an emerging financial hub, its recent experience with GUCCI failure and its strategic geographic location in regard to GUCCI topology.[16]

The DIFC is one the world's fastest growing international financial centers, with an aim to achieving the stature of New York, London and Hong Kong, and to facilitate economic development in the UAE and the region. It is strategically located between the established markets of Western Europe and the exploding economic growth of East Asia.[17] The DIFC is a 110-acre economic free zone with special regulations that has been operating since 2004 and has attracted international private sector firms from both the Middle East region and beyond. It also includes the NASDAQ Dubai stock exchange, which opened in 2005.[18] The DIFC has broad financial sector experience and interests, with activities spanning banking, brokering, capital markets, wealth management, reinsurance, captives and other financial services.

This event convened a unique combination of individuals, including world-class experts of all aspects of undersea cable infrastructure, senior financial sector and other stakeholders, and seasoned champions of international policy change.

[16] Dubai and other cities in the Middle East region were affected by multiple undersea communications cable cuts that occurred during the 12-day period of January 23 through February 3, 2008.
[17] Financial institutions may apply for licenses and can be eligible for benefits such as a zero tax rate on profits, 100% foreign ownership, no restrictions on foreign exchange or repatriation of capital, operational support and business continuity facilities. Financial services in the DIFC are regulated to international standards by the Dubai Financial Services Authority (DFSA).
[18] The stock exchange was formerly known as the Dubai International Financial Exchange or DIFX

2.7.2 Program

The Summit program progressively advanced through a detailed review of the intrinsic vulnerabilities of the infrastructure, the stakeholder interests and the proposed recommendations. The Summit format was highly interactive throughout in order to optimize participants' ability to offer insights and perspectives, as well as to influence the consensus development process. The program climax was the final day's Summit Council meeting. The Summit Council included senior private and public sector representatives of each of the 6 participating continents. The Council reviewed each of the proposed recommendations, clarified key points of articulation and laid out a strategy for implementation.

Table 3. ROGUCCI Global Summit Program

OCTOBER 26	OCTOBER 27	OCTOBER 28	OCTOBER 29
	TECHNICAL AGENDA	IMPACT AGENDA	Recommendation Agenda
	Expert Workshops Across 8 Ingredients (Environment, Power, Hardware, Software, Network, Payload, Human, ASPR)	Pleanary Program Outage History, Priority Concerns, from 8 Ananlysis, Financial Sector, Needs and Impact. Working Program Working groups to address gaps.	Policy Council Recommendation Articulation Startegy for Mobilization and Recommendation Implementation.
	Cable Ship Tour		
RECEPTION	Social Program	Social Program	

The technical agenda included a review of the eight ingredients of ICT infrastructure. For each of the eight ingredients, a volunteer session chair had been identified earlier from the online forums. These chairs helped facilitate discussion on the online forums and then led discussions among subject matter expert peers in the technical program. For each ingredient, the chairs sequentially walked through a systematic review of the intrinsic vulnerabilities, a discussion of relevant trends, a prioritization of concerns and a discussion of proposed recommendations. The purpose of the first part of the discussion was to be certain that no intrinsic vulnerabilities were missed and that the analysis foundation was complete in its coverage. The purpose of the second part was to understand the dynamics that could increase the presence of specific intrinsic vulnerabilities. For example, the increased marine activity associated with ocean sprawl elevates the concern related to the Hardware ingredient intrinsic vulnerability of susceptibility to damage. The third step was to call out areas of greatest concern. This was done based both on the insights gleaned from recent trends, and, more importantly, from the comprehensive intrinsic vulnerability review. In this way, latent failure modes were exposed and given proper attention. It can be said that this was a way of identifying "an unprotected cockpit door scenario on September *10th*" (to make reference to September 11, 2001 terrorist attacks). This method contrasts with most reliability and security work, which is based primarily on reacting to observed historic analogies or to gathered intelligence. However, such approaches can fail to sufficiently protect critical infrastructure from either manmade or natural causes, particularly when a latent failure mode is involved. The Ingredient leaders are listed below in Table 4.

Figure 11. Summit Program Snapshots

The impact agenda included presentations from stakeholders, with special emphasis on the international financial sector. Dr. Nasser Saidi, Chief Economist of the DIFC and Stephen Malphrus, U.S. Federal Reserve Board Chief of Staff, presented keynote addresses. In addition, other stakeholder interests were presented from other stakeholders: regulatory agencies and the international media. The stakeholders emphasized the devastating impact that the loss of international communications has on their operations, often rendering them incapable of accomplishing essential services. A special concern for the international financial sector is the unacceptability of payload latency. Delays in message delivery on the order of milliseconds can be a harsh competitive disadvantage. Government regulators stressed the importance of international connectivity for government operations and nation-state security. A television news reporter described the dependency of the international media on high bandwidth services in order to transmit news stories.

Table 4. Ingredient Chairs

Ingredient	Chair, *Affiliation*
Environment	Dr. Lionel Carter[19], *Victoria University*
Power	Richard Freeman[20], *Telstra*
Hardware	Dr. Nick Lordi, *Telcordia Technologies*
Software	Goff Hill, *GTel Consultancy*
Network	Peter Cornell, *AT&T*
Payload	Stu Goldman, *Bell Labs*
Human	John Harrison, *LanditD*
ASPR (Policy)	Mick Green, *ICPC and BT*

The Recommendation agenda consisted of a review of the proposed Recommendations by the ROGUCCI Global Summit Council. The Council was formed by two representatives of the six continents and included Dr. Curtis Siller, IEEE Communications Society President Emeritus, and Global Summit General Chairman, Karl Rauscher. The EastWest Institute Founder and President, John Mroz, served as the Council Chairman. Discussion included the important aspects of problem definition and background, required commitments, benefits if successful, alternatives and their consequences, suggested next steps and measures of success. As most of The Recommendations required 'outside of the industry' policy influence, the support of proven international policy change experience was essential to this final part of the program. For each of the Twelve Recommendations that emerged, a path forward was planned with the support of the technical and stakeholder communities in the room.

John Mroz and Dr. Curtis Siller
Figure 12.

2.7.3 Cable Ship Tour

In order to provide those less familiar with the industry with the opportunity for first hand experience with some of its critical equipment, a tour of a special cable vessel was an integral part of the program. A tour was arranged and hosted by E-marine of the cable ship *Etisalat* from its cable fleet. Of interest to the participants were the ship's special dynamic positioning system, the holding bays for the spare cable and the equipment and procedures used to lay and retrieve cable.[21] Also of interest was the fact that this particular ship and crew played a critical role in the repair of the cables from the high profile multiple

[19] Dr. Carter participated via teleconference, utilizing undersea communications cable infrastructure form New Zealand.
[20] While supporting the online forum discussions, Mr. Freeman was represented by Richard Krock (Bell Labs) during the Summit.
[21] Cable ships are highly specialized seafaring vessels that can vary widely in their dimensions and performance capabilities. The *CS Etisalat* was built to order by M/s. Masa Shipyard, Helsinki in 1990. Classified as a cable layer by the Lloyd's Register, the ship has a gross tonnage of 2221 with a cable uplift capacity of 700 tons and a speed of 13 knots with an endurance of 35 days. Its overall length is 74.5 meters and its maximum speed is 13 knots. It can accommodate 32 people.

cable cut crisis that had occurred the previous year.[22] The crew and vessel had braved 14-foot waves in order to act urgently in repairing damaged cables that had left the region with severely degraded connectivity.[23]

Figure 13. C.S. Eitsalat

Figure 14. Tour of C.S. Etisalat

[22] *Etisalat Management Recognizes Bravery of E-Marine Cable Repair Crews - E-Marine Heroes Successfully Restore Internet Connection to the Gulf*, www.etisalat.ae, 9 March 2008.
[23] "This was an extremely difficult period for the region's telecommunications industry. The cuts were extremely serious as many of the Gulf countries rely on submarine cables to provide access to international markets and Internet content. Accordingly, telephone and Internet services were seriously degraded." Omar Bin Kalban, CEO & Managing Director of E-marine PJSC, Ibid.

2.7.4 Participant Assessment

The Summit succeeded in raising critical stakeholder awareness, formulating actionable Recommendations, and prompting numerous requests for briefings. The twelve consensus Recommendations, if implemented, will improve the reliability of the global infrastructure. In addition, the individuals who took part in it rated The Summit as an overwhelming success (Figure 16).

Figure 15. Some of The Summit Participants

An electronic audience polling system was used to enhance the ability to gauge Summit participant sentiments in real-time. The polling system was used throughout the event to track perspectives. At the conclusion of The Summit program, the audience was polled to gauge overall assessment of value, commitment and interest in the event, process and future steps. As shown the Figure 16, 92% valued their participation as "time well spent," 91% expressed commitment to participating in follow-up activities, 90% want to see The Summit repeated, and 97% indicated that The Summit created a desire for more effort in this area.[24]

Discreet feedback was also sought and captured. Several points were stressed. These include expressed appreciation for the leadership provided by the ROGUCCI process in taking on a problem that was outside of the industry's ability to solve alone. One benefit that was underscored was the need filled by the ROGUCCI process in looking at the infrastructure at a global level. Other positive feedback centered around the value of effectively integrating the diverse disciplines and perspectives of the communications industry, stakeholders and international policy change agents. Still others expressed gratitude for the broad span of perspectives, which encompassed technical experts (such as those with manufacturing functions, or operational responsibilities for networks and cable ships) and senior executive leadership (e.g., CEOs and other decision makers). Other comments ascribed merit to the venue selection for its relevance as a financial sector stakeholder and for its historical significance. Finally, the most heartfelt feedback was directed toward the sense of cooperation that was achieved and the drive to commitment for breakthroughs in the current barriers to elevate the reliability of the global infrastructure.

Feedback was also provided in areas to strengthen the ROGUCCI process. First, participants recognized the need for effective engagement between existing, related fora and the ROGUCCI process. The process had engaged key international groups that deal with some aspects of undersea cable infrastructure.[25] However, as breakthroughs are pursued with the implementation of ROGUCCI Recommendations, effective engagement with these and other fora, as appropriate, will be important. As described in some of The Recommendations, the best role for these and other groups is still to be determined. They can either make adjustments to their missions and embrace additional responsibilities, or remain on their current course. In either case, effective complimentary relationships should be nurtured. Another opportunity to strengthen the ROGUCCI process is to provide more clarity about the continuity of the effort going forward. It is understood that as this is a new process there is a need to remain flexible.

[24] Note that it was not the intention of the ROGUCCI process to create an ongoing event. The question regarding future annual events was submitted from participants, who requested that the level of interest be assessed. Since the objectives of the ROGUCCI process are focused on having a positive impact on the world's critical infrastructure, flexibility will be maintained and the most appropriate follow-up activities will be pursued.

[25] Engagement or participation included the Financial Services Sector Coordinating Council (FSSCC), International Cable Protection Committee (ICPC), SubOptic Conference, the IEEE Oceanic Engineering Society as well as several nation-state level initiatives.

However, posting next steps and other follow-up materials on the ROGUCCI web site (www.ieee-rogucci.org) can be very helpful. A third area for improvement was one expressed for the whole industry, which needs to continue to nurture private sector-led initiatives that are facilitating collaboration with an aim to improving the reliability of the global infrastructure.

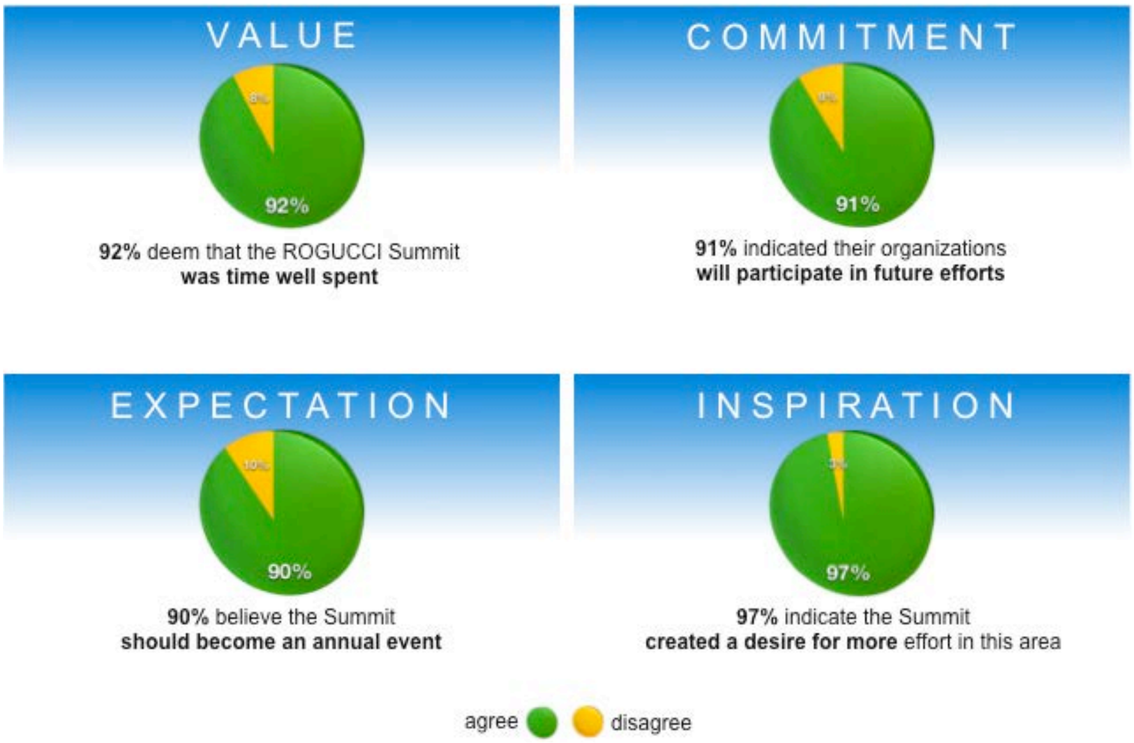

Figure 16. Summit Participant Assessment

2.7.4 Recognized Historic Event by Porthcurno Telegraph Museum

The ROGUCCI Global Summit was recognized as an historic event by the Porthcurno Telegraph Museum of Cornwall, U.K. The award–winning museum is dedicated to preserving the history of international undersea communications cables and is located at the site of a landing point of one of the first international cables.[26]

An historic note from the Museum that commemorates the ROGUCCI Global Summit is included in the front matter for The Report. The note reads, in part:

[26] In 1870, Porthcurno began its life as an important center of international communications. It was in this year that a chain of telegraph cables linking Britain with India was completed. Porthcurno was chosen as the landing point for the British end of this cable link. The company that laid the cable into Porthcurno was the Falmouth Gibraltar and Malta Telegraph Company, founded by John Pender in 1869 and one of four companies established to lay the cables in the 'chain' linking Britain and India. www.porthcurno.org.uk

There are only a few moments in history that capture a key turning point - Not just a decisive moment for an industry or technology but a shift to a greater awareness of our global communities' dependence on a hidden infrastructure. The ROGUCCI Global Summit in the autumn of 2009 will turn out to be such an event.

Porthcurno Telegraph Museum seized the opportunity to capture this event for future generations, to allow them to look back and review the details of a time when world class experts, stakeholders and champions of international policy change came together to share research after a yearlong study. We have submitted into our archives a time capsule of The Summit- including presentations, photographs and audio recordings which will be closed for 30 years but held for posterity.[27]

Museum Director Libby Buckley, who served as the curator of the ROGUCCI Global Summit, made extensive photography and audio recordings. She also provided a well-received presentation on the history of the undersea communications cable industry.

2.8 Contributors[28]

The ROGUCCI process relied upon the expertise and experience of world-class experts, and industry and government leaders from literally around the world. Engagements with these individuals took various forms, including interviews, small and large meetings, telephone consultations, online forum discussions, briefings and the Global Summit. Table 5 provides a summary of the many organizations that supported this effort. The degree of support varied widely - from brief consultations with just one person on a single important question or participation in the online forum, to efforts that involved a team of people who took on extensive research, analysis and championing of issues. The number of people engaged exceeded 300. The individuals and organizations that contributed to The Study have served an important cause for the benefit of people around the world.[29]

[27] Buckley, Libby, ROGUCCI Global Summit, Dubai 2009 Historical Note, Porthcurno Telegraph Museum, Cornwall, U.K. February 2010.
[28] Additional recognition is provided in Section 6, Acknowledgements.
[29] It should not be construed that the contributing organizations or individuals agree with every aspect of The Report.

Table 5. ROGUCCI Study Contributors

Contributing Organization	Country
2Connect	Bahrain
ABC News	International
Agora Cyber Charter School	U.S.
Alcatel-Lucent	Egypt, France, Saudi Arabia, U.K.
Alkhorayef Group of Companies	Saudi Arabia
ANACOM	Portugal
Associated Chambers of Commerce and Industry of India (ASSOCHAM)	India
Assured Networks	U.S.
AT&T	U.S.
Attorney General's Department	Australia
Australia-Japan Cable	Australia
Batelco	Bahrain
Bell Labs (Alcatel-Lucent)	U.S.
BITS Financial Services Roundtable	U.S.
Board of Governors, Federal Reserve System	U.S.
Booz & Company	Italy
BPI TelcoData	U.S.
BT	U.K.
Cable & Wireless	U.K.
Caldwell Marine International	U.S.
Central Bank of the U.A.E.	U.A.E.
Chairman, Joint Chiefs of Staff, Military (ret.)	Pakistan
China Reform Forum	China
China Telecom	China
China Unicom	China
Cisco	ME Region
Datawave	U.K.
David Ross Group	U.S.
Detica	U.S.
Digicom	U.S.
Dubai Financial Services Authority (DFSA)	U.A.E.
Dubai International Financial Centre (DIFC)	U.A.E.
Dubai School of Government	U.A.E.
E-marine PJSC	U.A.E.
EastWest Institute	Belgium, Russia, U.S.
Enginnovation	U.S.
European Commission, Information Society and Media Directorate General	EU
European Network and Information Security Agency (ENISA)	EU
Financial Services Sector Coordinating Council (FSSCC)	U.S.
Foreign Secretary (fmr.)	India
Furgo Offshore Surveys	U.S.
Gateway Gulf	Kingdom of Bahrain

General Cable Company	Germany
Go, Ethihad Atheeb Telecom Company	Kingdom of Saudi Arabia
Google	U.K.
GTel Consultancy	U.K.
Harvard Kennedy School of Government	U.S.
Hibernia Atlantic	Ireland
Huawei Marine Networks	China
Huawei Technologies Co., Ltd.	China
IABG mbH	Germany
IEEE Communications Society	International
IEEE Oceanic Engineering Society	International
Information Assurance Advisory	U.S.
Information Assurance and Cyber Forensics	U.A.E.
Institute of Electronics, Information and Communications Engineers (IEICE)	Japan
International Cable Protection Committee (ICPC)	U.K., International
International Mulitlateral Partnership Against Cyber Threats (IMPACT)	Malaysia
John Tibbles Consulting	U.K.
JPMorganChase	U.S.
KDDI	Japan
Kogakuin University	Japan
Korea Communications Commission	Republic of Korea
Landitd	U.K.
Level3	U.K.
Lucent Government Innovations	U.G.
Massachusetts Institute of Technology (MIT)	U.S.
Middle East Network Operations Group (MENOG)	ME Region
Ministry of Industry and Information Technology	China
National Center for Security and Crisis Management	Jordan
National Defense University	U.S.
National Emergency and Crisis Management Authority	U.A.E.
New Jersey Institute of Technology (NJIT)	U.S.
Nortel	Canada
NTT Communications	Japan
NYSE Technologies Ltd	U.K.
Office of The Telecommunications Authority	Hong Kong
Pennsylvania State University	U.S.
Pioneering Consulting	U.S.
Porthcurno Telegraph Museum	U.K.
Qualitynet	Kuwait
Qwest Communications	U.S.
REACH	Hong Kong
Reliance Globalcom	India
Renesys	U.S.
Renmin University of China	China
Rockbury Media International	U.K.

Russell White Marine Ltd.	U.K.
Sahara Net	Saudi Arabia
Science Applications International Corporation (SAIC)	U.S.
Secure 1st	U.A.E.
Southern Cross Cable Networks	Australia
Tarasul Telecom	Kuwait
TE Data	Egypt
Telchemy	U.S.
Telcordia Technologies	U.S.
TELE Greenland International	Denmark
Telecom Italia Sparkle	Italy
Telecommunications Regulatory Authority	U.A.E.
Telecommunications Regulatory Authority	Bahrain
Telefonica Int'l Wholesale Svcs.	Uruguay
TeleGeography Research	Slovakia
Telenor	Norway
Trusted Information Sharing Network	Australia
Tyco Telecommunications	U.S.
United Arab Emirates University	U.A.E.
University of Arkansas at Little Rock	U.S.
University of Ottawa	Canada
Verizon	U.S.
Victoria University of Wellington	New Zealand
Vodafone	Germany
Westpac	Australia

Figure 17. ROGUCCI Global Summit Participants, The Gate, DIFC.

3. ANALYSIS of UNDERSEA COMMUNICATIONS CABLE INFRASTRUCTURE

Undersea cable systems are *unique* among communications systems fundamentally in that they *traverse great distances* and they *operate under water*. However, the building block ingredients of undersea communications systems *are the same* as other communications systems. The *Eight Ingredient Framework of Communications Infrastructure* (or 8i Framework)[30] provides a useful way to understand, discuss and manage undersea communications systems and their intrinsic vulnerabilities (Figure 18).

> The 8i Framework is a systematic and comprehensive framework that a) consists of the ingredients that make up communications infrastructure, b) includes all of these ingredients, c) specifies the 8 ingredients of environment, power, hardware, software, network, payload, ASPR (Agreements, Standards Policy and Regulations; abbreviated as Policy) and human. This framework is used for understanding and mastering vulnerabilities, identifying disciplines, decomposing attributes, preparing for new technologies, and other studies that support network, security, and emergency preparedness.[31]

In order for a threat to have an impact, it must exercise an intrinsic vulnerability.[32] A key advantage of using the 8i Framework is that each of the ingredients has a *finite* set of intrinsic vulnerabilities. Thus, these intrinsic vulnerabilities can be addressed independently of specific threat knowledge. Further, since the intrinsic vulnerabilities are finite, using an approach based on them can provide the assurance of comprehensive coverage that is not achievable by a threat-based approach, where threats tend to be practically infinite because of countless permutations. Since most government and industry attention, energy and resources are currently applied to addressing threats, the future use of the 8i approach is very promising, as it can provide more economical and effective means of promoting high reliability and security of information and communications infrastructure. In addition, it can bring attention to areas that otherwise might not receive needed notice, but that can have devastating effects.

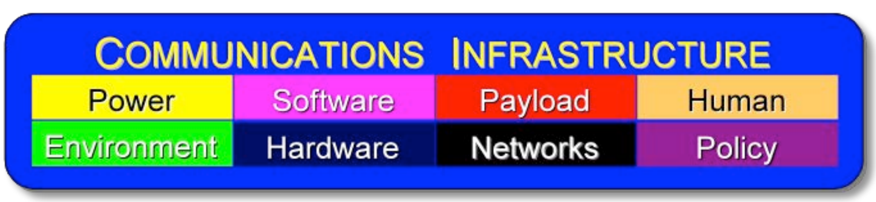

Figure 18. 8i Framework

This section reviews each of the ingredients with commentary specific to the undersea communications systems.

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[30] Rauscher, Karl. F., Protecting Communications Infrastructure, Bell Labs Technical Journal Homeland Security Special Issue, Volume 9, Number 2, 2004; Proceedings of 2001 IEEE Communications Society Technical Committee Communications Quality & Reliability (CQR) International Workshop, www.comsoc.org/~cqr .

[31] ATIS Telecom Glossary, www.atis.org .

[32] The communications industry has defined a **threat** as "*anything with the potential to damage or compromise the communications infrastructure or some portion of it*." The industry has defined a **vulnerability** as "*a characteristic of any aspect of the communications infrastructure that renders it, or some portion of it, susceptible to damage or compromise*." FCC NRIC VI Homeland Security Physical Security Final Report, December 2003.

3.1 Environment

3.1.1 Function

The Environment ingredient of communications infrastructure includes buildings, trenches where cables are buried, space where satellites orbit, locations of microwave towers and cell sites, and the floor of the ocean. The Environment is an essential ingredient of undersea cable systems, providing the location for the physical equipment. Because of the harsh conditions of undersea environments, undersea communications environments are some of the most challenging across all of the broadly defined information and communications industry. There are three types of environments for undersea communications cable systems:

In Air - Landing Stations

The beginning and ending points of submarine cable systems are landing stations. Landing stations are typically buildings with a controlled environment similar to that of a telephone central office or computer data center. The two primary functions of the buildings are to serve as a termination point for the submarine system and to provide a gateway to landline communications networks. Sometimes these functions are accomplished with two separate buildings at separate locations. In these buildings, air quality is critical. Thus, temperature, humidity and dust are carefully controlled in order to ensure that the electronic hardware has the proper environment in which to operate and fire control systems are designed to avoid damage due to fire extinguishing systems. These facilities also allow personnel to access hardware to make changes such as system upgrades and repairs.

In Earth - Buried Cable

Between landing stations and the deep sea is a transition environment. In this transition environment, the communications cable segments are buried either directly or within duct from the landing station to the beach. Cables are buried under the earth in order to protect them from being damaged. Damage can occur due to weather, e.g., induced erosion, subsidence, or lightning in the land section. Damage can occur on the beach due to storm induced cable exposure resulting in cable displacement and abrasion, and from vehicles, people, animals and debris. In water depths of 1000-1500m, cables are buried underneath the sea floor, wherever practicable, as the prime protection against fishing activity (including trawlers), boat anchors, sea creatures such as sharks, and debris being moved across the ocean floor by currents or by current induced abrasion.

In Water - Undersea

This is the predominant environment for cable systems. It is also the most unique and challenging because of the oceans' extent, wide range of current, temperature and pressure conditions and difficult access. In waters deeper than 1000-1500m, the cables are typically laid on the ocean floor. That depth range is beyond the present limit of trawl fishing – a major cause of cable faults A unique challenge of this environment is the high pressure.

3.1.2 Intrinsic Vulnerabilities

The following is a list of intrinsic vulnerabilities of the Environment ingredient.

- identifiable
- accessible
- exposed to elements
- dependence on other infrastructures
- contaminate-able
- subject to surveillance
- continuously being altered
- remotely managed

The landing station environment is heavily dependent on the people who maintain it and have access to it. Thus the Human ingredient is one that has many interactions with the Environment. In addition, the Environment is dependent on Power to operate equipment. When multiple parties share a location there will be expectations regarding the behavior of other people and systems, and thus the Policy ingredient plays a key role.

3.1.3 Significant Trends

There are ten significant trends that relate to the Environment ingredient.

▲ 1. The identification of cable route environments is becoming easier with the proliferation of information on the Internet.

▲ 2. Ocean sprawl is an emerging phenomenon as human activity in the marine environment increases. This activity includes the rapidly developing renewable energy schemes (wind turbines, wave power, tidal power), as well as increased exploration and exploitation of hydrocarbon resources in deeper waters beyond the continental shelf.

▲ 3. Aquaculture development is another trend as offshore fish farming is producing 50% of consumable fish as of 2009. "Wild" fisheries are also changing in response to over-exploitation of stocks and varying ocean conditions amongst other factors. This has seen some fisheries extend into more distant and deeper waters although extended fishing ranges may be curtailed by the price of fuel. Such trends are significant because as noted above, fishing activities are a major cause of cable faults.

▲ 4. Interest in deep-sea mining is increasing, with the focus on polymetallic (copper, iron, manganese, nickel and zinc) nodules, and metallic sulfides around seamounts and hydrothermal vents. Most of this mining interest is within the Pacific Ocean. The International Seabed Authority (ISA) organizes and controls activities relating to mineral resources on the seabed and ocean floor beyond national jurisdiction.

▲ 5. As onshore resources become scarce, there is an increase in coastal mining activity especially for sand and gravel for aggregates.

- 6. A new type of undersea structure is the cabled ocean observatory, which is a science-based monitoring and experimental site designed to evaluate many aspects of the ocean and seabed in order to learn how the marine environment "ticks" and changes with time.[33]

- 7. There is an increase in the number and size of ships. This is significant because anchors have been identified as the second major cause of cable faults. This trend has been accompanied by changes in shipping routes to meet the needs of developing economies such as China and India.[34]

- 8. There is increased use of ship positioning technology, which enables new, remote vessel surveillance with Internet access.[35] [36]

- 9. There is an increased trend in the establishment of marine protected areas in territorial and international waters.[37] [38]

- 10. The oceans' responses to present and projected changes in climate have the potential to affect the undersea cable network through intensification of natural hazards relating to [a] rising sea level, [b] changes in the frequency and intensity of storms that will influence wave and current effects on cables and [c] rainfall events that can increase floods to the point where river discharge forms turbidity currents with the potential to damage cables.

In summary, undersea communications cable stakeholders should be aware of the potential impact of the trends associated with the undersea cable environment and they should actively support existing industry efforts of continuous innovation and improvement that could help in this area. In addition, an area for consideration is a proposal for a study that addresses how changes to the ocean chemistry could degrade the current projected lifespan of cables already in place or about to be laid.

[33] The NEPTUNE observatory off Vancouver Island, for example, is based on a 800 km fiber optic cable system that provides power for submarine equipment and a means to transfer environmental data back to shore in real time.
[34] In 2007 there were 43,000 shipping units exceeding 1 billion dead weight tons compared to in 2005 where there were 40,000 shipping units exceeding 880 million tons, Institute of Shipping, Economics and Logistics.
[35] Universal Automatic Identification System (AIS) is a short range application used by ships and Vessel Tracking Systems (VTS) that supports the transfer of information between ships and land-based monitoring stations such as unique identification, location, speed and course.
[36] It is interesting to note that a ship dragging an anchor, which could cause multiple cable cuts, can be detected with this technology, but if the communication to remote monitoring center relies upon a damaged cable, the transport of the detection information may be impaired.
[37] Australia, for instance, has extended protection of the Coral Sea region to cover an area of almost 1 million square kilometers: likewise substantial areas of the North Atlantic have been identified for protection.
[38] U.S. President George W. Bush established nearly 200,000 square miles (518,000 square kilometers) as a protected marine environment area. January 2009.

3.2 Power

3.2.1 Function

The Power ingredient is vital to the operation of any communications infrastructure. Without power, communications systems fail to operate.

> During normal operation, power systems serve in the critical role of interfacing with commercial electric power to provide high quality electric energy for highly specialized electronic equipment. During extreme events, whether they are natural in origin – such as hurricanes and ice storms, or human in origin – such as power blackouts and terrorist attacks, power systems are essential. Without power, communications equipment fails to operate and communications services disappear.[39]

Power includes four basic components: the distribution plant, the battery plant, the generator plant, and the grounding system.

The designs often implement triplication to achieve adequate redundancy of all components in the power system and the ability to switch any power sub-system in or out. In addition, there is a need to ensure that maintenance practices are well designed and fully implemented. These often include practices such as keeping fuel supplies topped up and test running generators periodically.

In addition to power needed to support the terminating electronics at landing stations, repeater regenerators and optical amplifiers require power. This is achieved by actually using the environment – the seawater – as a conductor to complete the circuit.[40]

Given the great lengths of submarine cables, the power equipment used in these applications has some special considerations. Cables are typically powered from both ends, with opposite charges at either termination. The repeaters are powered by the potential across them. The current completes its circuit by passing through the metallic core of the cable and through the surrounding seawater. When the protective barrier around the metallic core is damaged such that its insulation properties are compromised, a short circuit occurs. The location of the short becomes the new virtual earth. However, the system can continue to operate as long as the power feed equipment from either end can provide enough voltage to support the required potential across each repeater. Otherwise the communications signals will reach the repeater and, being too weak because they cannot be amplified at the unpowered repeater, fail to progress any further. If a second loss of insulation occurs along the cable, the system will fail to operate, as there will be no potential between the two virtual earth points. For this reason the immediate repair of shunt faults is imperative.

[39] Krock, R., Rauscher, K., Runyon, J., Hayden, P., *Intrinsic Vulnerabilities of the Power Systems Supporting Communication Networks and Expert Strategies for Defense*, Bell Labs, 2007.

[40] The electrical conductivity of seawater has a significant dependence on temperature, a lesser dependence on salinity, and a relatively negligible dependence on pressure. Seawater conductivity is generally measured at 4.8 [S/m]. This compares to 63 x 10^6 [S/m] for silver, the best known metallic conductor and ~10^{-14} [S/m] for air.

3.2.2 Intrinsic Vulnerabilities

The following is a list of intrinsic vulnerabilities of the Power ingredient.

- distribution plant - loss of connectivity
- distribution plant - loss of potential[41]
- battery plant - critical fuel characteristics
- battery plant - load limitations
- battery plant - interface limitations
- battery plant - chemical damage
- battery plant - aging
- battery plant - physical damage
- generator plant- critical fuel characteristics
- generator plant - load limitations
- generator plant - wear
- generator plant - aging
- generator plant - physical damage
- grounding – loss of connectivity

The Power ingredient is also heavily impacted by other infrastructures, such as commercial power and transportation, and by other ingredients of the communications system, such as humans, environment, and policy.

3.2.3 Significant Trends

There are four significant trends that relate to the Power ingredient.

1. Submarine cable infrastructure is being extended into new areas as economies develop. This brings the risk that, for economic reasons, insufficient redundancy is built into the power supply system.

2. More developing regions are able to provide stable commercial power.

3. In some instances cost savings are driving less redundancy in power design than has previously been engineered.

4. The ocean is becoming the source of numerous alternative energy types.

[41] Earth potentials can be a serious threat to cable systems in areas of high magnetic-field activity. Root, H.G., *Earth-Current Effects on Communication-Cable Power Subsystems*, Electromagnetic Compatibility, IEEE Transactions, Issue 2, May 1979.

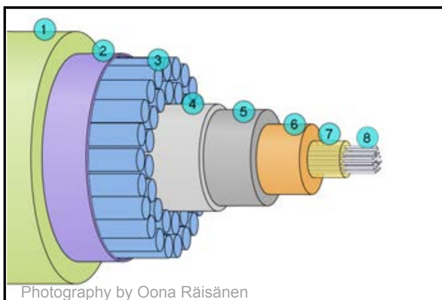
3.3 Hardware

3.3.1 Function

The Hardware ingredient of communications infrastructure includes equipment frames, semiconductor chips, electronic circuit packs and cards, and metallic and fiber optic transmission cables. While much of the hardware is similar to landline applications, in undersea communications systems, hardware components of particular interest are the special purpose fiber cables and inline undersea repeaters.

Undersea fiber cable construction

Modern undersea communications cables are based on fiber optic technology. Depending on the application, one of several types of cables may be used.[42] These include deep-water lightweight cables for depths beyond 8.5 km, abrasion-protected cables where difficult terrain or sea floor currents are an issue, deep-water armored cables for difficult terrains or sea floor currents at depths beyond 6km, light single-armored cable for shallow water applications up to 2km where the cable will be buried, heavy singled-armored cables for shallow water applications less than 1.5km, light double-armored cables for applications where the cable typically in depths less than 0.5km that include both buried and unburied sections, heavy double-armored cables in very shallow water less than 50m where anchors may be present, and special-purpose shallow-water cables for applications where fishing is done with trawlers and where burial is not an option. A typical undersea fiber cable construction is shown in Figure 19. The three primary challenges being addressed in undersea fiber cable construction are (1) keeping sea water out of the enclosure under very high pressure conditions, (2) corrosion of the enclosure, and (3) combinations of the two. For this reason, special measures are used in the construction. These include high-density polyethylene to provide an electrical insulation and to prevent seawater penetration, high tensile steel wires to provide strength and special metals, and hermetically sealed copper tubing to protect the optical fibers from the very small hydrogen molecule



1. polyethylene protective
2. high strength tape
3. steel wires
4. metallic water barrier
5. polycarbonate
6. metallic tube
7. petroleum jelly
8. optical fibers

Figure 19. Example of Undersea Communications Cable Construction[43]

[42] Chesnoy, Jose, *Undersea Fiber Communications Systems*, Academic Press, London, 2002. pp. 457-461.
[43] diagram from www.wikipedia.com .

3.3.2 Intrinsic Vulnerabilities

The following is a list of intrinsic vulnerabilities of the Hardware ingredient.

- logical design
- physical damage
- temperature range dependency
- field force influence – electric, electromagnetic
- adverse radiological interaction
- chemical contamination
- aging

The wet plant is more critical than the dry plant in terms of reliability because the MTTR is greater. Typical MTTR values give around 2 weeks for the wet plant repair instead of 2 hours for the dry plant. From a reliability point of view, this is why the failure rate for laser pumps used within the repeaters is a sensitive issue for the system. For example, typical failure rates for amplifiers in terrestrial networks are within 1000 to 10000 FIT[44] compared to submarine amplifiers, which are within 10 to 100 FIT (around 2 orders of magnitude lower).

Designing ultra reliable submarine systems means that the probability of a wear-out failure occurring during the system life must be near non-existent and the probability of random failure must be minimized as much as possible.

Repeaters are critical equipment as they contain electronic, optical and opto-electronic components. In addition to that, one must keep in mind that any internal damage, whatever the cause is, may directly impact the transmission quality. Consequently, careful precautions must be taken to prevent and reduce the risk of failure. In particular, an optical failure occurring on a specific fiber must not affect the system performances of the other fibers. The tests required before and during the cable installation are detailed in [ITU-T G.976].

Undersea networks require reliable and robust fiber optic systems to avoid costly repairs in the wet plant. Moreover, considering that technologies may change during the life of the system, a maintenance scheme should be established at the beginning of system life to ensure timely repairs during the contractual system lifetime.

Failures occurring during the system life may be due to internal faults (shunt fault, fiber loss increase, repeater failures, card failures, etc.) or external aggressions (e.g., anchors and fishing activities for wet plant and mis-operation for dry plant).

3.3.3 Significant Trends

There are eight significant trends that relate to the Hardware ingredient.

- 1. Undersea cable systems are typically designed for a 25 year life time.[45] However, as new systems come on-line with much greater capacity, older systems are being retired prior to 25 years.

[44] The Failures In Time (FIT) rate of a device is the number of failures that can be expected in one billion device-hours of operation (once in about 114,155 years).
[45] As specified in ITU-T Recommendation G.977. The usual requirement for system reliability is less than three failures requiring cable ship intervention during the system's designed lifetime.

Thus, systems are not experiencing the increased failure rate due to aging towards the end of a system life.

- 2. In recent years, it appears that submarine cable faults due to components have been dramatically decreasing. Available data suggests that they now account for less than 10% of all faults.[46] [47] (Figure 20)

- 3. Advances in laser and Dense Wave Division Multiplexing (DWDM) technology have greatly increased the volume of payload throughput in new, and already deployed, fiber cables. Upgrades can be made to some existing systems that dramatically increase their potential useful life span.

- 4. Hardware components tend to continue to be unique for a given cable system.

- 5. There have been advances in introducing standardized equipment used in cable repair activities.

- 6. The repair and maintenance of undersea cables continues to rely on very specialized ships. The availability of these vessels remains limited, the significance being that this limitation affects the time to repair and the number of simultaneous repairs that can be performed.

- 7. A limiting factor for individual undersea cable capacity continues to be the combined weight of cable and repeaters.[48]

- 8. While the broadly defined information and communications technology industry is experiencing economic devolution, the undersea communications cable infrastructure remains a long term investment.

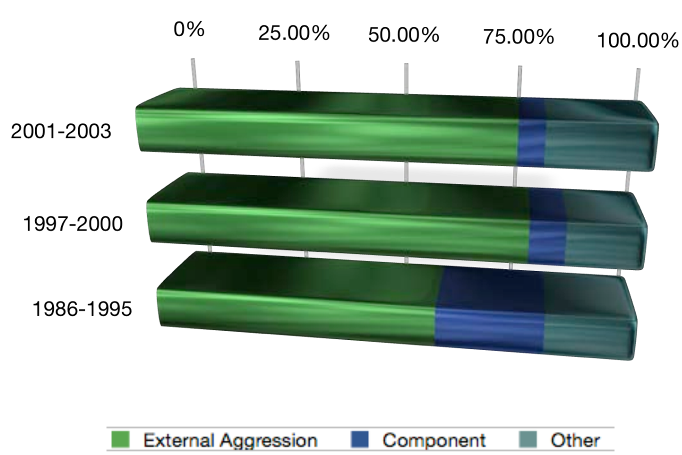


Figure 20. Overall Causes of Fiber Optic Cable Failures, 2004[49]

[46] Worldwide Trends in Submarine Cable Systems, http://www.scig.net/Section11a.pdf ; fault data from ICPC, was analyzed for a period of 15 years.
[47] Trends in Submarine Cable System Faults", Tyco and Alcatel-Lucent, http://www.suboptic.org/Uploads/Files/WeA1.2.pdf
[48] More fibers would require more repeater components and thus heavier repeater chassis. The tensile strength of the cables limits the weight that can be hoisted during repairs.
[49] Worldwide Trends in Submarine Cable Systems, http://www.scig.net/Section11a.pdf .

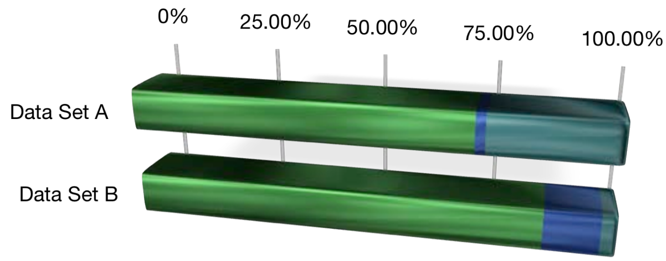


Figure 21. Overall Causes of Fiber Optic Cable Failure, 2007

Possible reasons for the decrease in component faults include:

Low failure rates are obtained through the use of heavily screened components, close control of raw materials, robust and simple design, careful manufacturing process and thorough quality control.

Redundant configurations are generally used to achieve the required reliability and to reduce the failure rate of the subsystems accordingly. For example, redundant pump laser configurations are usually employed to ensure that the amplifier reliability target is met.

The industry follows specifications developed in the mid-1990s.[50] These standards have also been updated in the last few years, and include cable parameters (mechanical and electrical), optical repeater parameters (power, jitter, amplification,), mechanical repeater parameters (housing, corrosion protection, insulation, etc), cable joint parameters (optical and mechanical parameters such as splice loss, mechanical and tensile strength) and system design characteristics.

[50] ITU-T G.971 to G.978 series of standards; These standards include: [ITU-T G.971] ITU-T Recommendation G.971 (2007), General features of optical fibre submarine cable systems, [ITU-T G.972] ITU-T Recommendation G.972 (2004), Definition of terms relevant to optical fibre submarine cable systems, [ITU-T G.973] ITU-T Recommendation G.973 (2007), Characteristics of repeaterless optical fibre submarine cable systems, [ITU-T G.974] ITU-T Recommendation G.974 (2007), Characteristics of regenerative optical fibre submarine cable systems, [ITU-T G.975] ITU-T Recommendation G.975 (2000), Forward error correction for submarine systems, [ITU-T G.975.1] ITU-T Recommendation G.975.1 (2004), Forward error correction for high bit-rate DWDM submarine systems, [ITU-T G.976] ITU-T Recommendation G.976 (2007), Test methods applicable to optical fibre submarine cable systems, [ITU-T G.977] ITU-T Recommendation G.977 (2006), Characteristics of optically amplified optical fibre submarine cable systems, [ITU-T G.978] ITU-T Recommendation G.978 (2006), Characteristics of optical fibre submarine cables, [ITU-T G.Sup.39] ITU-T G-series Recommendations – Supplement 39 (2006), Optical system design and engineering considerations.

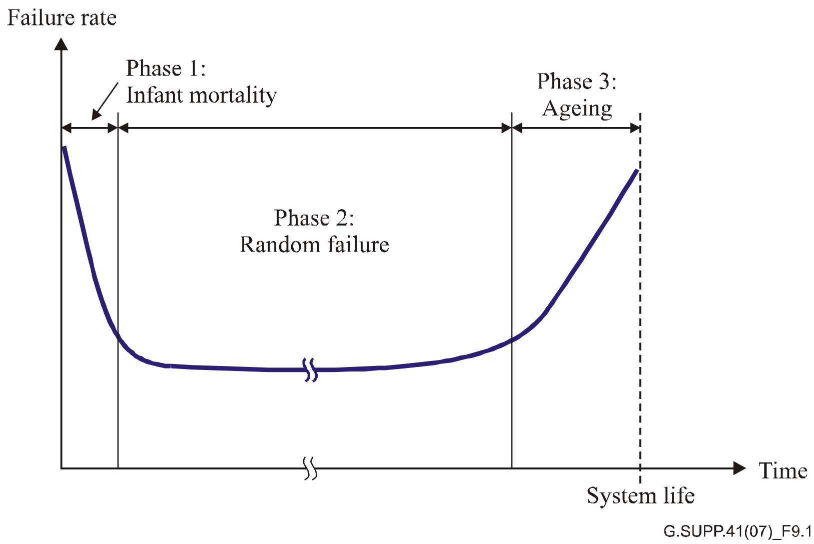


Figure 22. Typical failure's rate behavior during the life of a system[51]

In summary, equipment suppliers of cable and other system components should continue to follow and adhere to the international standards for submarine cable systems. Industry experts should continue to support ongoing standards activities to promote continuous improvement in reliability performance of undersea cable components.[52] In addition, undersea cable system procurements should continue to include reliability and design specifications included in international standards.

Like everything else man-made, a given cable infrastructure has a finite life. Given that many fiber optic cables are reaching their projected end of life, additional consideration should be given to managing the end of life period. This can include establishing a range of probable life spans along with identifying the limiting causes and the end of life failure modes.

[51] As specified in ITU T G-series Recommendations – Supplement 41.

[52] For example, ITU Study Group 15, (Optical transport networks and access network infrastructures) is currently investigating the characteristics of optical fiber submarine cable systems. ITU is specifically asking for comments on: Specifications of terminal equipment and optical fiber submarine cables in optical fiber repeatered submarine cable systems with various optical amplifiers such as Erbium Doped Fiber Amplifiers (EDFAs) and Raman amplifiers; Specifications of terminal equipment and optical fiber submarine cables in optical fiber repeaterless submarine cable systems, including systems with remotely pumped optical amplifiers; Specifications of test methods concerning the terminal equipment, optical fiber submarine cables and other equipment relevant to the submarine cable systems; Specifications of forward error correction (FEC) for optical fiber submarine cable systems.

3.4 Software

3.4.1 Function

The Software ingredient of communications infrastructure includes the programs that provide both the functionality and the fault management capabilities. Software includes the development and test loads, version control and management, chain of control deliver, and stored software releases. Relative to the other ingredients, the function of software in undersea cable systems is not unique.

3.4.2 Intrinsic Vulnerabilities

The following is a list of intrinsic vulnerabilities of the Software ingredient.

- ability to control (render a system in an undesirable state, e.g., confused, busy)
- mutability of deployed code (patches)
- accessibility (during development, distribution, rootkit to control kernal/core)
- logical errors
- complexity of programs
- discoverability of intelligence (reverse engineer, exploitable code disclosure)
- incompatibility (with hardware, with other software)

3.4.3 Significant Trends

There are five significant trends that relate to the Software ingredient.

- 1. Software will have more control in future networks (e.g., mesh topologies).
- 2. Most other areas of the ICT industry rely increasingly on outsourcing software development. The undersea cable system software appears to be fighting that trend.
- 3. Software is expected to have increased sophistication for handling real-time sensitive applications in the context of non-real-time sensitive applications that are heavy users of bandwidth.
- 4. Software must increasingly be capable of processing complex combinations of services and co-mingled data and control messages.
- 5. Software will be upgradeable to extend the capabilities and life of systems.

In summary, aggressive testing of software is warranted to ensure not only that it works as expected, but that it correctly handles conditions at the boundary values and beyond. Exception handling is particularly important for a system that "can't" go down. Each node should be able to protect itself from a failure of the other nodes, and from all possible stimuli regardless of how unlikely or illogical.

3.5 Network

3.5.1 Function

The Network ingredient of communications infrastructure includes the configuration of nodes and their interconnection; network topologies and architectures; various types of networks, technology, synchronization, redundancy, and physical and logical diversity; and network design, operation and maintenance.

3.5.2 Intrinsic Vulnerabilities

The following is a list of intrinsic vulnerabilities of the Network ingredient.

- capacity limits
- points of concentration (congestion)
- points or modes of failure
- complexity
- dependence on synchronization
- interconnection (interoperability, interdependence, conflict)
- uniqueness of mated pairs
- need for upgrades and new technology
- automated control (*via software)
- accessibility (air, space or metallic or fiber)
- border crossing exposures

3.5.3 Significant Trends

There are five significant trends that relate to the Network ingredient.

- ▲ 1. There is increasing network capacity being delivered with status quo physical route diversity: There is substantial growth in capacity being made available, however it is typically not being deployed with proportionate physical diversity – most notably due to the same landing points being used or routes tracing the same geographic "choke points". The significance is that stakeholder dependency on undersea cables is increasing, which exposes them to greater negative impact when a system failure occurs.

- ▲ 2. There is new undersea cable connectivity in global regions of emerging economic growth.

- ▲ 3. There is a parallel evolution path with generic optical networks advances such that undersea network software will likely track closely with advances in terrestrial networks.

- 4. There is a move by network operators toward mesh topologies, based on non-ring protected wavelengths which creates new levels of economic, technical and service complexity and risk. But the economics are too attractive to the network operators to ignore.

- 5. There is a trend for nation-states to establish corridors for cable routes. These corridors present a trade-off of the disadvantage of concentrating cables into a single point of failure, with the advantages of a designated protection zone for cables with the potential for more effective enforcement of restrictions on anchoring and trawling.

In summary, better international cooperation and coordination is needed to create more alternate paths through sovereign waters without onerous regulatory requirements or costs. In addition, an international framework for cable system operators, network operators and service providers to cooperate in defining and implementing best practices would be helpful.

3.6 Payload

3.6.1 Function

The Payload ingredient of communications infrastructure includes the information transported across the infrastructure; traffic patterns and statistics; information interception; and, information corruption. It includes both normal data transport and signaling and network control traffic. There are special latency considerations for payload delivery due to the long distances of undersea cable systems.

3.6.2 Intrinsic Vulnerabilities

The following is a list of intrinsic vulnerabilities of the Payload ingredient.

- unpredictable variation
- extremes in load
- corruption
- interception
- emulation
- encapsulation of malicious content
- authentication (mis-authentication)
- insufficient inventory of critical components
- encryption (prevents observability)

3.6.3 Significant Trends

There are ten significant trends that relate to the Payload ingredient.

1. Traffic demand is increasing at its fastest rate.

2. As a percentage of the total traffic, financial services traffic is decreasing year over year.[53]

3. Advances in laser technology have increased the throughput capacity of existing fiber facilities.

4. Encryption algorithms are evolving and the more robust algorithms may require the most "extra" bandwidth to carry the encryption.

5. Compression algorithms may be used more to carry only the unique information and allow reconstruction of the payload at the far end.

6. Traffic load variation is increasing at both intra-day and inter-days intervals.

[53] High bandwidth applications like video and gaming require orders of magnitude more bandwidth. However, most recognize that the new applications are less important to critical needs like economic stability.

- 7. The risk of interception is increasing through development of new technologies.
- 8. The risk of payload emulation is increasing.
- 9. The risk of the encapsulation of malicious content is increasing.
- 10. Authentication needs to be more sophisticated today given the increasing sophistication of the malicious agents.

In summary, the laws of physics do apply here. Increase in distance and retransmission will increase the delay. Very time sensitive messages will benefit from priority on the most direct routing and perhaps benefit from forward error correcting schemes to avoid the need to retransmit when an error is detected. A list of the various applications, their characteristics and their requirements needs to be compiled. Since corruption at the lowest level is always possible, forward error detection and repair is viable for cable. Means must be developed to at least detect, if not prevent, interception either directly or indirectly from the cable. A flip side to interception is emulation of what appears to be valid payload but may be inserted by a "man in the middle," a concern that must be detected and blocked. A policy needs to be established regarding the transport of encapsulated malicious content. Sufficient authentication and authorization needs to be performed by the access networks prior to entering the cable backbone.

3.7 Policy

3.7.1 Function

Agreements, Standards, Policies and Regulations (ASPR) is a term used to refer to the complete set of inter-entity arrangements that are necessary for communications services. These arrangements include national and international standards; federal, state and local regulations or other legal arrangements; or any other agreement between entities - including industry cooperation and agreements and other interfaces between entities.[54] ASPR provides the necessary mechanisms used to anticipate, improve and control the behaviors of entities that design, develop, implement, operate and evolve communications networks. ASPR is abbreviated here as 'Policy'.

Several factors make Policy a unique ingredient in undersea communications infrastructure. These factors include the sharing of cable routes, the international scope, the jurisdiction of maritime law and law of the sea, the influence of fishing regulations, the need for long term standards and the vital need for coordinated speedy repairs.

3.7.2 Intrinsic Vulnerabilities

The following is a list of intrinsic vulnerabilities of the Policy ingredient.

- Lack of ASPR (agreements, standards, policies, regulations)
- Conflicting ASPR
- Outdated ASPR
- Unimplemented ASPR (complete or partial)
- Interpretation of ASPR (mis- or multi-)
- Inability to implement ASPR
- Enforcement limitations
- Boundary limitations
- Pace of development
- Information leakage from ASPR processes
- Inflexible regulation
- Excessive regulation
- Predictable behavior due to ASPR
- ASPR dependence on misinformed guidance
- ASPR ability to stress vulnerabilities
- ASPR ability to infuse vulnerabilities
- Inappropriate interest influence in ASPR

[54] ATIS Telecom Glossary, www.atis.org .

3.7.3 Significant Trends

There are eight significant trends that relate to the Policy ingredient.

▲ 1. The use of Automatic Identification System (AIS) has proved invaluable in determining the cause of some submarine cable faults and has also revealed the extent of faults caused by the anchors of vessels that are underway. As can be seen in Table 6, the best-understood causal distribution has changed significantly in recent years.[55]

Table 6. ICPC Loss Prevention Bulletin

Cause	Pre 2007	2007 - 2008
Fishing	**67%**	**33%**
Anchors	8%	**48%**
Dredging	2%	0%
Other	23%	19%

▲ 2. Some nation-states require permits to be issued before cable repair operations are allowed to commence. This process introduces delay to the repair operation that can be significant and increases risk of multiple cable failures.[56]

▲ 3. There is increased concern over the risk of pirate or terrorist attacks on a cable ship on the high seas. Given the special role of these vessels and crew in regard to global critical infrastructure, it is unclear as to whether the international community would place the appropriate priority on the need for quickly resolving such a crisis.

▲ 4. The failure of some coastal nation-states to comply with UNCLOS continues because they have not enacted domestic legislation to protect submarine cables, have not updated existing legislation to comply with UNCLOS, or do not enforce existing legislation.[57]

▲ 5. While there is improved cooperation amongst operators in several areas, there remains a lack of sufficient information available to stakeholders to make appropriate statistical calculations related to critical parameters such as expected loss of service, duration of outages and latency impact.

▲ 6. The commercial interests of private sector equipment suppliers, network operators and service providers continues to include effective forces for promoting the continued improvement of undersea communications cable systems. These forces include competition, the return on investment, drive for efficiency and thus improved quality, and the natural accountability that

[55] Since 2006 cable owners have observed 21 submarine cable faults around the UK alone. There were 10 cases of anchor damage to submarine cables and all involved vessels that had been underway with their anchors deployed. Some of these vessels also damaged multiple cables during the same event.

[56] Conflicting boundary claims compound the delays that can be caused for those states/countries requesting permits before repair operations commence in circumstances where the estimated location of a fault falls close to or within area of conflicting boundary claim i.e. multiple permits to repair are require. The cable owner perspective is that there is no legal or practical reason for requiring permits before repairs are undertaken.

[57] Active submarine cable systems were extensively damaged by depredations in 2007. Actions are piratical under UNCLOS 100/101 and violate UNCLOS 113. These incidents were unprecedented in the history of submarine cables and caused tremendous disruption to the telecommunications network. A cable ship also returned to a buoyed cable, following a return to port for operational reasons, to discover the buoy, rope and section of cable stolen. There is potential for an exceptionally long outage if remanufacture of equipment is required to bring any depredated cable system back into service.

occurs from the observability of service outages or other impairments throughout the communications services supply chain.

▲ 7. There is a growing number of stakeholders for which highly available and resilient undersea communications cable infrastructure is vital. Fewer and fewer of these are direct bandwidth customers of cable network operators. As this ratio of stakeholders-to-customers increases, there is a growing gap between the commercial focus of the private sector and critical infrastructure assurance needed at a global level.

▲ 8. Expectations regarding the rights of access and activity on the seafloor is changing as there is increased interest in exploitation for mining.[58]

In summary, it is imperative to support existing industry efforts of continuous innovation and improvement in this area. Specifically, some stakeholders of highly reliable and resilient GUCCI in the course of due diligence may want to enhance their current understanding to include intrinsic vulnerabilities and potential for latent modes of failure.

1. The global community of nations can recognize the vital priority of repairing damaged undersea cables and eliminating the long delays for permits for repair work.[59]

2. The protections for cables can be strengthened. Consideration can be given to the implementation and enforcement of minimum precautions to be taken by vessels to secure anchors prior to sea passage. In addition, consideration should be given to enacting or updating national laws to align with international cable protection provisions.[60]

3. Operators of undersea communications systems can be pro-active in cooperating in a trusted information sharing community to ensure that the assembly, analysis and generation of appropriate statistics are available to support the needs of the stakeholders of this critical global infrastructure.

4. The undersea cable industry can coordinate with relevant Government agencies to develop a protocol that will provide a fast and coordinated response in the event of pirate attacks. As part of the protocol, points of contact can be established for cable owners for such emergencies.

[58] International Seabed Authority (ISA).
[59] Consideration should be given to a) reinforcing the duty of nations to cooperate in repairs, b) reducing repair permits/licenses/fees/guard boat requirements for all repairs to international cables beyond territorial seas, c) according cable repair ships innocent passage status for the purpose of undertaking repairs in territorial seas.
[60] e.g., UNCLOS.

3.8 Human

3.8.1 Function

The Human ingredient includes the human involvement throughout the entire lifecycle of activities related to the communications infrastructure (design, implementation, operation, maintenance and de-commissioning); intentional and unintentional behaviors; limitations; education and training; human-machine interfaces; and, ethics and values.

In addition, it is helpful to consider the human dimension in two roles. The first is when it is actually a part of the infrastructure; i.e. when humans are part of the complex chains of equipment suppliers, network operators, and service providers of the systems. In this context the human is an ingredient that is essential to the infrastructure. Important aspects of this role are that humans have an element of immediate, direct control of some aspect of the infrastructure, and the infrastructure organization has some control over the human. The other role is where the human is outside the infrastructure. In this role the human is not an ingredient of the infrastructure, but rather may be an ingredient of another infrastructure or may serve as a threat agent.[61] In these situations, there is indirect control over the infrastructure (as when the human is part of the shipping infrastructure), and the communications infrastructure has considerably less control over the human (as when serving as a threat agent).

People have a vital role in the design, testing, implementation, monitoring, maintenance and repair of undersea cable systems. Several factors make Human an ingredient deserving of special attention in undersea communications infrastructure.

These factors include the high stakes potential associated with the payload of cable networks, the human interface with great natural and engineering challenges, the need for highly specialized knowledge and skills and the related need for execution of critical tasks, and the concern for sabotage or unintentional damage.

3.8.2 Intrinsic Vulnerabilities

The following is a list of intrinsic vulnerabilities of the Human ingredient.

- physical (limitations, fatigue)
- cognitive (distractibility, forgetfulness, ability to deceive, confusion)
- ethical (divided loyalties, greed, malicious intent)
- user environment (user interface, job function, corporate culture)
- human-user environment interaction

[61] The potential damage that malicious agents could inflict by attacking a relatively few number of cables is considerable, given that these cables have such huge capacity. This can be thought of as an example relating to the 'new asymmetric terrorist threat' which is causing concern to many nations; It does not take much imagination to extend upon existing published analysis to see the parallels to undersea cable infrastructure. *Maritime Critical Infrastructure Protection: Multi-Agency Command and Control in an Asymmetric Environment*, Watts, Robert B, www.hsaj.org/pages/volume1/issue2/pdfs/1.2.3.pdf;

Some of these intrinsic vulnerabilities are more present in undersea communications networks than terrestrial networks. For example, workers on repair ships on the high seas may be away from family for extended periods of time, exposed to unusual workplace dangers and require highly specialized expertise. Also, undersea cable consortia are more and more competing on price to deliver large bandwidth with a resulting focus on reducing costs. If an existing route is known to be acceptably reliable from natural or man-made damage then there is a great commercial incentive to lay cables along the same route. This reduction in diversity and resilience has at its root the human intrinsic vulnerability associated with cognitive decision-making. It is interesting when looking at solutions to this vulnerability, to break this cognitive aspect down further into the analytical performance of the decision maker and the psychological factors that could influence the decision maker.

3.8.3 Significant Trends

There are seven significant trends that relate to the Human ingredient.

- 1. The Internet has made extensive information available to the public about undersea communications technology, network deployments and operations.
- 2. The workforce involved in undersea communications cable infrastructure tends to be older, relative to other ICT benchmarks.
- 3. Some governments now classify undersea optical fiber cables as "critical infrastructure."
- 4. Over 70% of cable faults are caused by what is termed "external aggression." Most often these aggressions involve human activity - fishing, shipping activity. This is an example of influence from the human ingredient outside this infrastructure.
- 5. In recent years, there has been increasing concern over maritime piracy and theft, the later being motivated by fluctuations in the price of metals.[62] These are examples of the human serving as the threat agent.
- 6. Competitive pressures increasing with evidence from dramatically reduced prices for bandwidth over the past decade.
- 7. Economic drivers to reduce cost leads to reduced diversity of cable routes and less collaboration between consortia because of competition.

In summary, the human vulnerabilities ingredient may be the most "frustrating" one. When we find bugs in the hardware or software, the mitigation is usually a new release with the bug removed. This is not an option with people. After a human mistake occurs, warnings are posted on how to avoid making the same mistake in the future, but people tend to forget and the same error occurs yet again. Therefore mitigations need to consider preventative measures to be incorporated via avenues of the other ingredients.[63] The undersea communications cable industry and stakeholders should establish a trusted information sharing community in order to ensure that essential infrastructure security information is shared with peers in a timely manner.

[62] Thieves may not know the difference between legacy metallic cables and fiber cables.
[63] i.e. hardware and software features to assist the human in avoiding mistakes.

4. KEY OBSERVATIONS FOR GUCCI

This section presents information that is related to the current and future reliability of GUCCI. It includes basic tutorial-level information for the reader previously unfamiliar with this industry, as well as key insights from peers for those most experienced in it. It contains 100 observations that are key to understanding the broad range of factors that influence the reliability, resilience and robustness of this critical international infrastructure. These 100 Key Observations, which provide important support for the guidance presented in The Report, were drawn from the 10,000+ data points that were part of The Study. The observations are foundational to the twelve Recommendations, as is evidenced in Section 5 and are referenced there throughout.

To ease the reading of each Observation, care has been taken to present them in a concise fashion as shown in the figure below.

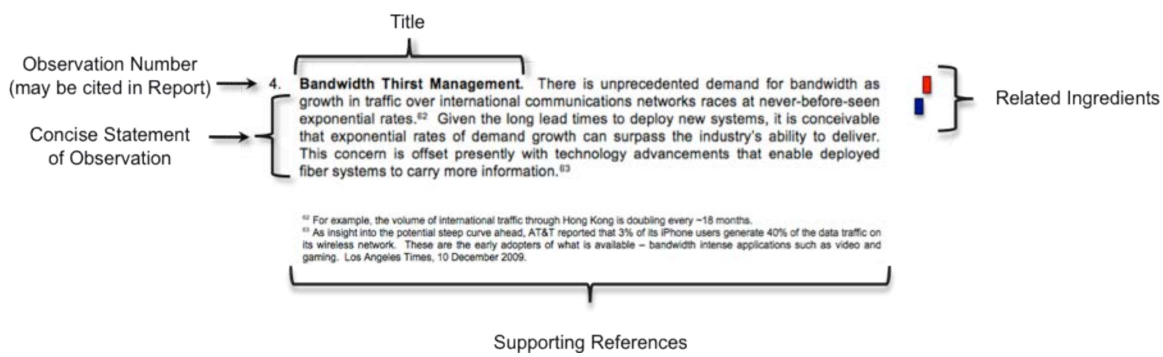


Figure 23. Presentation of Key Observations.

Each observation is accompanied with an indication as to which of the eight ingredients it is related to. These indicators are provided as a color key reference in the right hand margin to assist the reader in quickly identifying Observations of interest for specific ingredients.

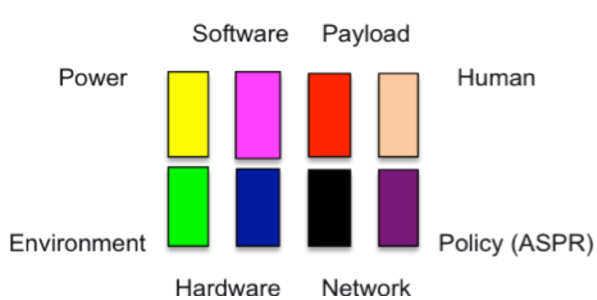


Figure 24. 8i Framework Colored Indicators for Ingredient Associations

The Observations are structured into four main categories, as outlined immediately below, to assist the reader. The corresponding number of observations for each category is shown.

Stakeholder *(20)*

Science & Engineering *(40)*

Business & Investment *(17)*

Government & Inter-Government *(23)*

The Observations begin with the Stakeholder perspective. All the effort going into building and maintaining this vast infrastructure is for their interests. Thus **the Stakeholder is the primary driver** for the business and other decisions affecting GUCCI. The Stakeholders includes any user. Consistent with the design of the ROGUCCI Study, the financial sector is emphasized here as a key stakeholder. A quick glance at these Observations reveals that they are primarily related to the Payload ingredient, as is evidenced from the frequent red indicators (■). The Stakeholder interests are embodied in the Payload that traverses the infrastructure. The next category used deals with **principles of Science & Engineering that enable and limit** the infrastructure. The laws of the physical world are strict in their rigidity. This is a good thing when we can harness them for technology. But they can also be constraints when they bound a possibility. It is not surprising that many of the ingredients are in play as science and engineering factors directly relate to each of them. The third category utilized covers the **Business & Investment aspects that react to opportunities** presented by the Stakeholder drivers and Science and Engineering enablers and limits. The Final category is the **Government & Inter-Government policy, which also shape what is do-able and not do-able**. Each nation-state legitimately seeks to represent its interests in inter-governmental engagements. There are also issues within a country that affect GUCCI. Because ASPR are manmade, unlike scientific principles, they are artificial constraints and therefore changeable. The ROGUCCI process, with its extensive analysis of authoritative source material in each of these essential four categories, incorporates the nature of each as described above.

Due to rapid developments in technology and business environments, the quantitative information used in the Observations is presented in *orders of magnitude*.[64] More specific information would quickly be outdated.

For additional reading on undersea communications cable infrastructure, the reader is directed to the material appended to The Report, the many books on the subject or specific technologies utilized, and the Internet. The industry has maintained a discipline of recording its history and providing ample records of its underlying science, engineering advances, systems deployed, routes traversed, landing points, regions served, special techniques developed, maritime fleets and many other details. Much of this information is readily available in the public domain.

The following sections present the 100 Key Observations in the four categories described above. The reader is encouraged to make reference to them, as appropriate, when reading The Recommendations in Section 5.

[64] 'Order of Magnitude' is an engineering and scientific method of describing quantities in approximation to emphasize the intuitive or general meaning of the quantity with deliberately less emphasis on the precision of the measurement. The Report uses the most common base of 10.

4.1 Stakeholder Oriented Observations

1. **Public Unaware.** Members of the general public are largely unaware of the significance that undersea communications cable infrastructure has in their daily lives and businesses. This dependence is very real and is evidenced in orders, transactions, research, technical support, media updates, and many other areas of society and business operations (Figure 25).

2. **More Bandwidth ≠ More Resilience.** User demands to date are impressive in motivating the build out of needed bandwidth, but are incomplete in motivating resilience investments appropriate for the level of dependence on GUCCI, and the consequences of its long term loss (Figure 25).

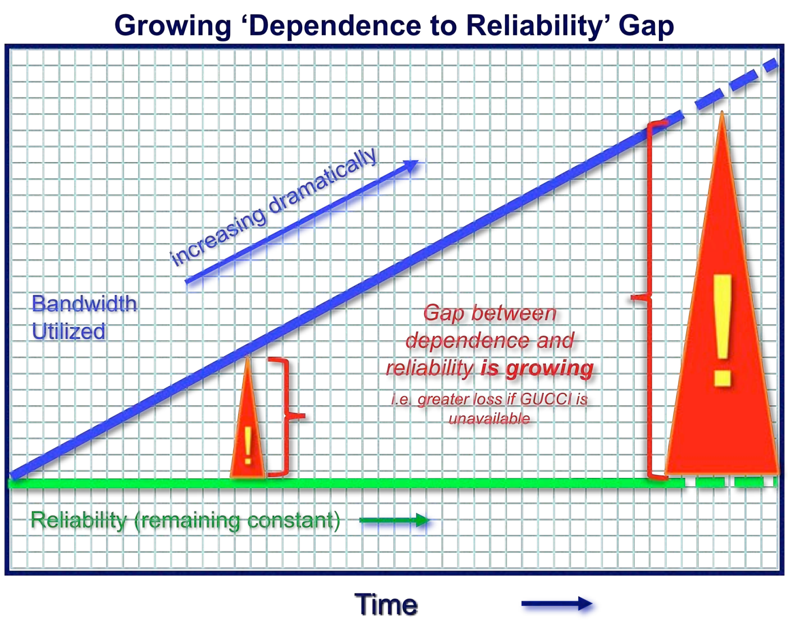


Figure 25. Growing 'Dependence on Reliability' Gap

3. **Heads in the Clouds.** Many consumers and business managers incorrectly believe that their international communications are carried via satellites links. As such, they may have a false sense of security regarding their understanding of critical dependencies.

4. **Bandwidth Thirst Management.** There is unprecedented demand for bandwidth as growth in traffic over international communications networks races at exponential rates.[65] Given the long lead times to deploy new systems, it is conceivable that exponential rates of demand growth can surpass the industry's ability to deliver. This concern is offset presently with technology advancements that enable deployed fiber systems to carry more information.[66]

[65] For example, the volume of international traffic through Hong Kong is doubling every ~18 months.

[66] As insight into the potential steep curve ahead, AT&T reported that 3% of its iPhone users generate 40% of the data traffic on its wireless network. These are the early adopters of what is available – bandwidth intense applications such as video and gaming. Los Angeles Times, 10 December 2009.

5. **User Expectations Are High.** The nature of communications network traffic is evolving from voice and messages to images, video, and other sophisticated applications, with general characteristics of being larger in size and more complex. Users have quickly extended expectations for high reliability from beyond traditional services to those that are advanced and emerging.

6. **Traffic Growth Is Part of Development.** Developing countries are experiencing disproportionately larger growth in traffic.[67]

7. **Everybody Wants It.** There are both *new* and *more* stakeholders for reliable GUCCI.

8. **Pacific Rim Leadership.** The steepest traffic growth area for undersea communications is trans-Pacific connectivity.[68]

9. **Bank on It.** The financial sector's evolution to a largely electronic infrastructure has been accomplished through reliance on international communications.

10. **"Snap to a Halt!"[69]** The loss of communications services has an immediate impact on international financial services sector, which have become almost completely electronic.

11. **Financial Sector Sensitivity.** Due to the recent economic downturn, global leaders have a heightened sense of appreciation for the cascading impacts of financial sector degradation. However, they may not have a sufficient appreciation for the rapidity at which it can occur. Degradation is conceivable through a technological failure of international electronic connectivity that would instantaneously freeze assets and prevent transactions.

12. **The Technologically Blind.** Stakeholders are typically not technically oriented and *do not focus on the technology* that they are using, but rather only its ability to meet their needs. Even if they were so inclined, because of the complexity of networks, it would be very difficult for them to know which cable systems they are actually depending on for specific types of communications.

13. **You Get What You Pay For - Maybe.** Sophisticated customers tend to distribute their dependence across multiple cable systems. However, due to common physical paths, this does not guarantee them of geographic diversity.

14. **Two Modes of Awareness**. There is wide variation of awareness within the financial sector and among other key stakeholders regarding their dependence on undersea cable infrastructure. The vast majority is largely unaware of the dependence and a very small minority has an advanced appreciation.

[67] The international Internet traffic growth has exceeded 100% for three regions: Middles East (160+%), Eastern Europe (140+%) and South Asia (110+%), TeleGeography Research, 2009.
[68] TeleGeography Research, 2009.
[69] U.S. Federal Reserve Board chief of staff Stephen Malphrus has coined this phrase to describe the instantaneous transfer of impact from the loss of communications services to the financial sector. Keynote Speeches, IEEE CQR International Workshop, London, June 2006, and IEEE ROGUCCI Global Summit, October, 2009.

15. **Emerging Role of Operational Risk**. The Bank for International Settlements Basil II Accord establishes operational risk as one of the three fundamental components of risk that a bank manages. This operational risk includes losses that could stem from internal processes, people and systems, and external events. Given the tight integration of the financial sector with international electronic communications networks, intensified cooperation between the financial and communications sectors is imperative.

16. **Financial Sector Due Diligence.** Insufficient reliability data is available for financial sector and other stakeholders to support needed risk calculations. In order to do appropriate diligence, stakeholders should be able make statistical predications regarding the expected frequency and duration of outages and the range of impairments (e.g., payload latency) that can affect their operations. However, insufficient data is available to support such analyses.

17. **Waiting.** Financial sector stakeholders have expressed an eagerness for more complete statistical information about the reliability of GUCCI.

18. **Waiting for My Ship to Come In.** The limited number of specialized cable repair ships is a top concern for stakeholders in some regions. Many undersea cable systems have a zone maintenance agreement (ZMA), in which the risks, costs and repair vessels are managed across multiple systems.[70]

19. **Nation-State Stakeholders.** The protection and integrity of GUCCI remains a focus of nation-states for both security and economic protection interests.[71]

20. **Resigned to Learn the Hard Way.** Those stakeholders aware of the latent vulnerabilities of global undersea communications cable infrastructure are generally resigned to work within the current paradigm of incremental improvement based on lessons learned from historical outages. The expectation is that a widespread catastrophe has to be experienced before the political will can be established to take necessary actions to address latent vulnerabilities.[72] [73]

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[70] The Atlantic Cable Maintenance Agreement (ACMA) covers the North Atlantic and South Atlantic Oceans (and also the South Pacific on the west coast of South America; the Mediterranean Cable Maintenance Agreement (MECMA) covers the Mediterranean Sea; and the Mutual Assistance Agreement for Pacific and Indian Ocean Cable Maintenance (PIOCMA) supports cable systems in the Pacific and Indian Oceans (www.piocma.com).

[71] The U.S. President's National Security Telecommunications Advisory Committee (NSTAC), a Federal Advisory Committee Act (FACA) body has included undersea cable infrastructure in its studies and guidance to the White House. NSTAC Chair Letter to President Barak Obama and *NSTAC Response to the Sixty-Day Cyber Study Group*, March 2009, Pages 10-11. (www.whitehouse.gov/files/documents/cyber/NSTAC%20Response%20to%20the%20Sixty-Day%20Cyber%20Study%20Group%203-12-09.pdf), *NSTAC Report to the President on International Communications,* August 12007, page 6., *An Overview of the Use of Submarine Cable Technology by UK PLC*, Centre for the Protection of National Infrastructure (CPNI), March 2006.

[72] The concern with this scenario is that given the profound dependence on communications infrastructure that has developed so rapidly, it is uncertain as to whether societies will be able to absorb the impact of catastrophic critical global infrastructure failure with its cascading effects.

[73] This mindset appears to carry across the human condition, as physician Scott Stoll notes: *"Prevention is the wisest, but hardest medicine."* www.drscottstoll.com/ .

4.2 Science & Engineering Oriented Observations

21. **Rare Glimpse of c's Limit**. Usually the speed of light makes communications appear instantaneous for humans. However, long haul undersea cable systems provide a rare human experience with the finite nature of the speed of light on the earth. A trip encompassing the circumference of the earth requires approximately one tenth of a second – a delay noticeable to a human. During cable failure alternate routes that require routing over longer distances than normal is common, resulting in latency that is unacceptable for some real-time sensitive applications.[74]

22. **99+%.** Nearly all long haul inter-continental communications traffic is carried through undersea communications cables. Less than 1% of inter-continental traffic is carried via satellites.

23. **Alternatives Are Not Up in the Air.** Satellite back-up alternatives to undersea communications cable infrastructure introduce latency that is unacceptable to real-time sensitive modes of communications and do not have sufficient bandwidth to meet current demands.[75]

24. **Payload Volume**. The payload traversing undersea communications cable infrastructure is on the order 30 terabits per second (30,000,000,000,000), and increasing at a rapid rate.

25. **Repeaterless Range.** Recent advances in fiber optic technology support propagation over distances of up to 500 km (~300 miles) without a repeater.

26. **Digital to Analog to Digital.** The historic progression of undersea communications began with the use of Morse code, which is a form of digital communications.[76] The bandwidth of these 1850s systems was about two words per minute. One hundred years later, in the 1950s, undersea cable analog telephony was introduced with a bandwidth of 36 simultaneous 4 kHz phone calls. Modern systems are digital once again, transmitting hundreds of millions of simultaneous telephone calls.

27. **DWDM.** A key technology for concentrating so many distinct signals in fiber optic communications is wavelength-division multiplexing (WDM). This is a method of using different frequencies of light to carry individual signals. This multiplexing can be

[74] The speed of light is ~3.0×10^8 meters/second, which would take 0.13 seconds to travel ~4.0×10^7 meters, the circumference of the earth.

[75] There are three main reasons for this. First there is a finite frequency domain within any medium. For earth-space-earth transmissions the same "free space" is utilized; whereas each fiber optic strand provides a new complete frequency domain. Second, undersea fiber optic cables are capable of much greater traffic loads - on the order of terabits (10^{12}, or 1,000,000,000,000); whereas satellites offer bandwidth on the order of megabits (10^6, or 1,000,000). Third, satellite transmission paths are considerably longer and the latency introduced with this longer path (recognizable for many from news interviews with subjects in isolated regions) is unacceptable for some critical applications, such as those associated with financial markets.

[76] However, Morse code is not binary, but rather quinary, as five elements are needed to represent all alphanumeric characters.

bidirectional over a single fiber strand. Dense WDM (DWDM) uses optical multiplexing techniques to further increase carrying capacity.

28. **Protocol Soup**. Synchronous Optical Networking (SONET) and Synchronous Digital Hierarchy (SDH) are protocols for multiplexing. They are standards that define the transfer of multiple digital bit streams. Synchronized networking ensures precise coordination rates across networks by the use of atomic clocks.[77] Future networks will likely increasingly rely upon Multiprotocol Label Switching (MPLS) or something similar, which is able to assign labels to data packets independent of their protocol and forward them based solely on the label content. MPLS can handle SONET, Ethernet and other data link layer technologies.

29. **Dynamic Rerouting.** Capabilities are being developed to automatically reroute traffic with software controls when a failure is detected. This capability is based on the availability of alternate routes and spare capacity to complete such rerouting, however.

30. **Fiber Pair Count.** The number of fiber pairs in a system is typically on the order of 10.[78] While systems can physically contain on the order of 100 pairs, there are limiting factors. These limitations include the maximum repeater weight that can be handled by the cable as it is lowered into and lifted from the water. In addition, the amount of time required to repair such a system relative to acceptable weather conditions has been cited as a consideration.

31. **Heavy Light Technology.** In addition to the foundation of light amplification by stimulated emission of radiation (laser) technology, there are numerous advanced photonic physics applications in a modern fiber optic transmission system. These include both linear and nonlinear all-optical amplifiers. An example of a linear amplifier is Erbium-Doped Fiber Amplification (EDFA), which uses an erbium-doped segment of a fiber to increase the intensity of the optical signal by exciting the erbium atoms to higher orbits. Raman amplification, on the other hand is nonlinear, and utilizes a lower frequency signal photon to induce inelastic scattering of a higher frequency pump photon that produce yet another signal photon.[79]

32. **High Voltage.** Given the great lengths of submarine cables, the power equipment used in these applications has some special considerations. Cables are typically powered from both ends, with opposite charges at either termination. The electric potential generated is in the range of 1,000 to 15,000+ Volts. Current flows are typically on the order of 1 Ampere, with variations of no more than an order of magnitude.

33. **Ground Water.** The signal repeaters are powered by the potential across them. The current completes its circuit by passing through the metallic core of the cable and returning by way of the surrounding seawater. The ocean completes the circuit.

34. **Out on *Two* Strikes.** When the protective barrier around a cable's metallic core is damaged such that its insulation properties are compromised, a short circuit occurs. The

[77] Prior to synchronized networks, Plesiochronous Digital Hierarchy (PDH) was used. This scheme coordinated networks to run at nearly the same rate.
[78] 4 to 8 pairs are common.
[79] Named after Sir Chandrasekhara Venkata Raman, who discovered the inelastic scattering of a photon in liquids, for which he received the Nobel Prize in Physics in 1930.

location of the short becomes the new virtual earth. However, the system can continue to operate as long as the power feed equipment from either end can produce enough voltage to provide the minimum needed potential across each repeater. If a second loss of insulation occurs along the cable, the system will fail to operate, as there will be no potential between the two virtual earth points.[80]

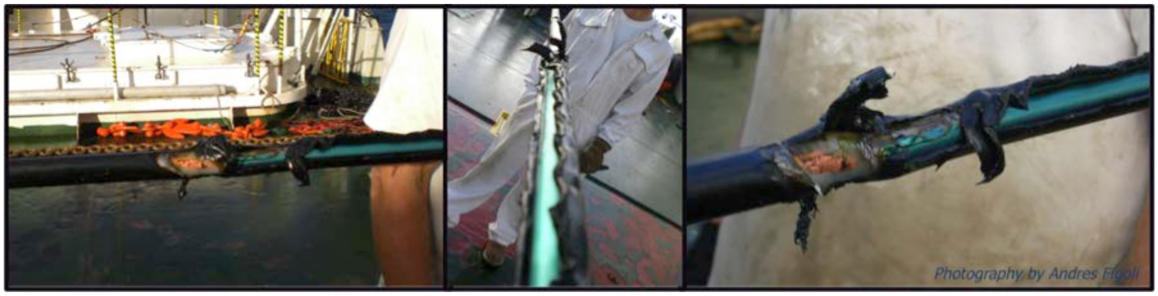

Figure 26. Shunt Fault

35. **As Thin As Your Hair.** Optical fibers have a diameter on the order of 10 microns.[81] The fiber is glass - typically made from silica (silicon dioxide, SiO_2), which is found in sand and quartz, and is one of the most abundant minerals on the Earth.[82] The long, thin, cylindrical strands form a waveguide that keeps light within its core as the refraction index of the material and geometry cause the light to be reflected internally as it passes along its length.

36. **Fiber Splicing**. The repair of a broken fiber strand so that it can again serve as a continuous optical waveguide, was once thought to be impossible. It is now performed routinely, however with a process that requires great care and precision. Fusion welding uses heat to join two fibers end to end. The result is a joint in which light passing through does not scatter or reflect backwards.

37. **Cause Analysis.** Because of limitations to monitor the vast spans of the seafloor that host GUCCI, the root cause analysis of many outages results in imprecise conclusions. The most frequently exercised intrinsic vulnerability is hardware's susceptibility to physical damage. This can be confirmed. However, the exact source of external aggression that acted as the threat agent is often not determined. Attribution for most outages is categorized generally as damage caused by anchors and fishing.[83]

[80] For this reason the immediate repair of shunt faults is imperative, in order to avoid an outage.
[81] Single mode; multi-mode fibers tend to be an order of magnitude larger in diameter.
[82] Doping is used to achieve attenuation levels suitable for long haul distances.
[83] www.iscpc.org

Figure 27. Cut Cable and Offending Anchor

38. **Statistical Analysis.** Modern communications networks are designed to be highly reliable. Therefore, outages are rare events. This means that specialized approaches are needed for understanding the likelihood of outage events and expected future downtime. For example, the frequency distribution of outages can often be well represented with a Poisson distribution.

39. **Not a Role Model *Yet*.** The current level of industry cooperation demonstrates significant progress, but comes short of supporting trusted sharing of outage data so that a global reliability performance level can be calculated.[84]

40. **Heroic Technology Breakthroughs.** Developments in Dense Wave Division Multiplexing (DWDM) have enabled existing fibers to be utilized to support greater throughput – on the order of 100 times more. "Butler's Law" predicts the amount of data coming out of an optical fiber is doubling every nine months.[85] [86] Fiber Optic technology is able to support transmission speeds of 40G across long haul distances, and 100G across shorter distances. Continued advances are expected.

41. **Silver Anniversaries.** Undersea cables have design lives of 25 years.

42. **Highly Reliable Components.** Undersea communications software and hardware are designed with ultra-high reliable requirements – typically some of the highest standards in the broad ICT industry.[87]

43. **Seeing the Light.** Transmission medium switched from metallic (copper) to optical fiber in the 1980s.

44. **The Gravity of It All.** The early undersea cables, which relied on an outer protective cover of gutta-percha as an insulator, were buoyant.[88]

[84] A role model example of private sector cooperation – including among competitors – to measure and improve infrastructure-wide reliability performance can be seen in the nearly two decade cooperation of the ATIS Network Reliability Steering Committee. www.atis.org/nrsc. Under non-disclosure agreement and with the use of a trusted third party, industry members share outage data, conduct joint expert analyses on causes and produce statistical descriptions and reports.
[85] Bishop, David, *Architects of the Internet: Speeding Net Traffic with Tiny Mirrors*, EETimes, September 2000.
[86] This is keeping pace with "Nielsen's Law", which predicts a 50% annual increase in connection speed from a usability perspective. *Nielsen's Law of Internet Bandwidth*, Nielsen, Jakob, www.useit.com/alertbox/980405.html, April, 1998.
[87] Ultra-high reliability expectations were established throughout the industry's history. For example, the first transatlantic telephone system (TAT-1), was built in the mid-1950s by AT&T (what is now Tyco Telecommunications), along with the British Post Office and the with the Canadian Overseas Telephone Corporation. It supported 36 analog telephone circuits simultaneously. TAT-1 performed flawlessly for more than two decades. When it was retired in 1978, the system had not experienced a single component failure. www.tycotelecom.com/pdfs/tyco_history.pdf

45. **Varying Degrees of Protection.** Undersea communications cables can be deployed at depths on the order of 10km (~ 6 miles).[89]

46. **Like a Garden Hose.** Undersea cables vary in diameter based on the manufacturer and the extent of protection. Cables in environments with more activity (i.e. near shore lines) call for more protection. Cables in deeper oceans require less protection.

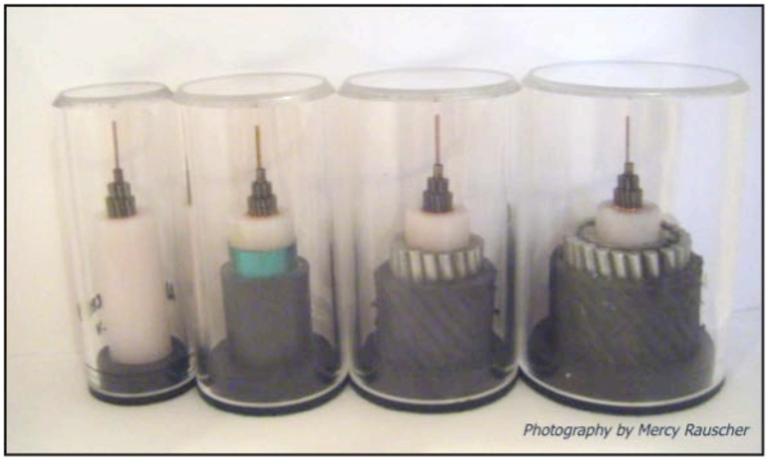

Figure 28. Example of Undersea Cables - Minimum to Maximum Protection[90]

47. **Recipe for Success**. The materials used in the manufacturing of undersea communications cables are carefully selected based on many factors. These include weight, electrical conductivity, contribution to tensile and other strength considerations, contribution to bending radius, chemical interactions with other materials used, affects of high pressure on them, contraction and expansion, longevity and cost.

48. **Information Smorgasbord.** There is a proliferation of information in the public domain, and especially on the Internet, on all aspects of undersea communications cable infrastructure.[91]

49. **Visibility Means Accessibility.** Undersea cable systems, landing points and shipping vessels are identifiable and therefore accessible.[92]

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[88] The first undersea cable, deployed in 1850, required weights to sink to the sea floor.
[89] The deepest part of the ocean known to man is found in the Mariana Trench located in the Western Pacific east of the Mariana Islands. The recorded depth extends to 11,033 meters. Water column pressures at this depth are on the order of 100 megapascals (over 15,000 psi), which is 1,000 times the standard atmospheric pressure at sea level. en.wikipedia.org/wiki/Mariana_Trench.
[90] Example shown at Alcatel-Lucent OALC4 family. Depicted are the Lightweight (LW) [17 mm], Lightweight Protected (LP) [23 mm], Single Armored (SA) [31 mm], and Double Armored (DA) [46 mm].
[91] Appendix A provides examples of the range and details of information available on the Internet.
[92] This is an intrinsic vulnerability of the Environment Ingredient, discussed in Section 3.

50. **Looking Backwards.** Most risk analysis and preparations are limited to previously experienced failure modes. However, senior experts recognize latent modes of failure. The consequences of a long-term outage from some of these failures could be catastrophic.

51. **Intrinsic Vulnerability Approach.** Stakeholders for highly reliable and resilient global undersea communications infrastructure would enhance their current understanding by including systematic coverage of intrinsic vulnerabilities and actively anticipating the potential impact of latent modes of failure.[93]

52. **SPOFs.** GUCCI has several geographic aggregation points that present latent single points of failure. The probability of a failure to occur at one place is much higher than for at multiple places simultaneously. Points of concentration are an intrinsic vulnerability of the Network ingredient.[94]

53. **Landing Sites**. The landing stations and their approaches from the sea are avenues that concentrate multiple cables and therefore present a particular concern from a physical diversity perspective.

54. **Back on Land.** Terrestrial routes are being deployed as alternatives to undersea routes.[95]

55. **Basic Topologies.** There are several geometric arrangements used for connectivity. Factors used to determine the topology include economic, number of connection points, and the distance. Branching is used when connectivity is needed along the way between two points. A ring architecture provides two simultaneous transmissions and can recover automatically when one path is cut. A collapsed ring trades reliability for capacity. A mesh network provides more alternate pathways but has less reserve capacity assurance. (See Figure 29.)

[93] Section 3.
[94] Section 3.5.2.
[95] *Reliance Takes Silk Road to China*, Lightreading.com, 26 August 2009.

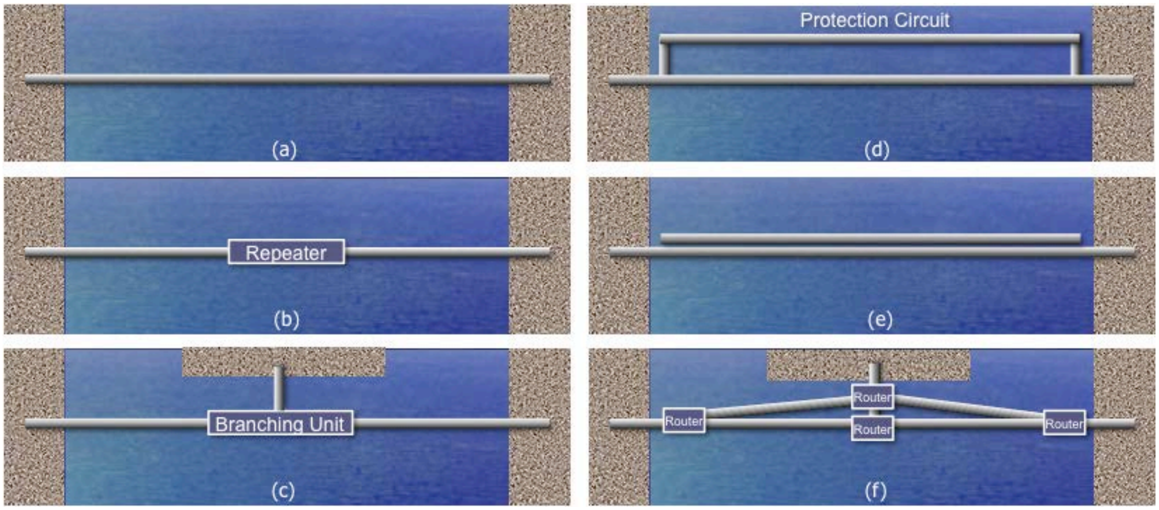

Figure 29. Basic Network Topologies.
(a) repeaterless, (b) repeater, (c) branching, (d) ring, (e) collapsed ring, and (f) mesh

56. **Collapsed Rings.** Many undersea systems that were originally deployed as Synchronized Optical Network (SONET) Rings, have been collapsed, or otherwise opened, which results in networks without the protection of a ring topology. This is done to increase capacity, however, it has exacted a cost on redundancy.

57. **Mesh Topology.** There is increased use of mesh network topologies. If designed with spare capacity, these geometric arrangements can offer increased resilience by offering multiple paths to maintain connectivity. If reserve capacity is not managed, then a single failure could result in substantial impairment of service.

58. **No "Plan B".** There is currently no alternative to GUCCI for providing high-speed broadband connectivity among the continents.

59. **Hurray Up - and Wait.** Damaged undersea cable outages have extended durations for three primary reasons: weather, contention for limited resources and government permitting processes for access to sovereign waters.

60. **Swelling Marine Activity**. There is currently an unprecedented level of human activity in the oceans. This includes the combined ocean sprawl in the form of wind turbines, wave power, tidal power, hydrocarbon access, deep sea and coastal mining, deployment of cabled ocean observatories, and an increase in the number and size of ships. An example of a displaced activity is aquaculture development in the form of fish farms, which are reducing deep-sea fishing activities. The reliability concern here is that environments can be altered by human activity in a way that can be harmful to the integrity of cables.

4.3 Business & Investment Oriented Observations

61. **Investing Billions.** Investment in new cable infrastructure for the next 3 years is expected to exceed that of the past six. The current investment level is on the order of $2 billion annually. This investment peaked in 2001 when investment exceeded $13 billion.[96]

62. **Build Cost.** The total initial cost to construct a long haul undersea cable system is on the order of $100M to $1B.

63. **Maintenance Cost.** The annual cost to maintain an undersea cable varies across regions. It is generally on the order of $100 to $1000 per km.[97]

64. **Price Variation.** The price for monthly bandwidth lease can vary widely depending on the points being connected. For example, a 10 Gbps wavelength can range from the order of $10,000 to $100,000.

65. **Nothing But Time.** It takes several years to plan and build a new undersea communications cable system.

66. **Competitive Differentiation.** Cable system operators are very sensitive to outage data that may reflect negatively on the perception of their system's performance.

67. **Small Community.** Relative to other communications networks, the number of undersea communications cable equipment manufacturers and system operators is small.

68. **Better than the Alternative.** Undersea communications cables are more economical and generally less susceptible to damage than are terrestrial cables.[98]

69. **Internet Underpinning.** The dramatically increased intercontinental connectivity capacity achieved in the 1980s was an essential aspect of the growth of the Internet.

70. **Game Change.** The undersea communications cable industry has shifted from one where competition was primarily between service providers exclusive ownership of systems to one where competition is based on bandwidth cost.

71. **Business Impact Disconnect.** Contracts between cable system operators and service providers typically include Force Majeure clauses that exclude operators of any obligation for the downtime associated with a damaged cable. This legal insulation is understandable because the cause of cable damage is seldom attributable to cable system operators. However, the resulting limited awareness of financial and other

[96] TeleGeography Research, 2009.
[97] Costs for the Pacific tend to be nearly double those for the Atlantic.
[98] The NRSC has observed that cable cuts are historically the most frequent cause of widespread outages in the United States public communications networks. www.atis.org/nrsc.

impacts of outages, isolates cable system operators from the feedback loop common to many commercial interfaces. This isolation makes operators less aware of the growing impact of downtime on end users.

72. **The Road More Travelled.** The re-use of existing cable routes is common practice for new system deployments. The motivations are at an individual system level, being primarily financial for the business and safety for the cable.[99] However, global infrastructure reliability considerations are not a primary consideration.

73. **Business Appetite**. Business investors tend to prefer the relative *low risk* option of placing cables along certain existing routes (whose safety is known) to meet new demands, as opposed to pioneering new routes with more uncertainties. The result is that there is less physical diversity than if more investment was made in new, alternative routes.

74. **Specialized Cable Ships**. Cable ships and their crews are typically shared resources. Contention for such limited resources is one of the contributing factors in extended duration outages, particularly when multiple cuts are involved.

75. **Paying Tolls.** Many undersea cable routes involve tariffs, rights of passage fees and similar expenses levied by nation-states.

76. **Spare Capacity.** With the exception of Asia-Europe routes, most routes have considerable "unlit" capacity, though at current traffic growth rates this existing capacity will be exhausted within a few years.[100]

77. **Maintenance Access.** Even if cable system operators were given advance permission to enter sovereign waters, there could be new requirements placed on them at any time.

[99] Planners first define the markets they want to serve, and landing points flow from this. Then they seek the shortest and safest routes, in order to minimize cost of cable and maintenance. The shortest path to deep water is usually taken, where risks are less, so the cable can be unarmored. In depths greater than 2,000 m cable is normally much safer and can be manufactured without armor, thus reducing risk, maintenance, manufacturing and installation cost. Planners of early undersea cables generally chose the shortest, safest routes between communications hubs. Consequently, distance and safety are the major motivators in re-using routes. This leads to concentration in some areas, since alternate routes may be longer, more expensive or more dangerous. In addition, costs to explore new routes can be avoided. Other factors include unknown risks, relationships with new nation-states, securing rights and the extent of research associated with a new area.

[100] TeleGeography Research, 2009.

4.4 Government & Inter-Government Oriented Observations

78. **Geo-politics.** Geo-political impediments have limited the implementation of a fundamental sound principle of reliability engineering – avoiding single points of failure. While certainly very serious, these limitations are artificial in the sense that they are manmade and unlike the rigid limitations of physics and other scientific parameters being managed in the pursuit of high reliability.

79. **Paperwork.** The procedure for a repair vessel to obtain approval for entering waters to restore service in some countries is very complex and can introduce significant delay in to the repair procedure.[101] It appears that for some countries the process can vary and suggests gross lack of planning and coordination on the part of the government.

80. **Confusing Boundaries.** There is wide variation among countries' claims on their territorial rights relative to its adjacent waters.

81. **Need to Go the "Extra Mile".** Several nation-states require repair vessels to obtain a permit for the repair of communications cables, including activity that takes place beyond a nation-state's territorial sea, normally 12 nautical miles (NM) from the coastal baseline (Figure 30).[102] [103]

82. **UNCLOS.** The United Nations Convention on the Law of the Seas (UNCLOS) provides special status for undersea communications cables, including special provisions for their protection.[104] [105]

83. **EEZ.** The UNCLOS establishes Exclusive Economic Zones that grant nation-states special rights for the exploration and use of marine resources. The EEZ extends out to 200 nautical miles from its coast (Figure 30).

84. **Continental Shelf Access.** Nation-states are entitled to lay undersea communications cables on the continental shelf, with conditions related to natural resources, the course taken, navigation channels and regard for cables or pipelines already laid (Figure 30).[106] [107]

[101] Equipment supplier-provided data showed two modes of repair for faults and outages. One mode had a dramatically much longer duration, which was due to extended permitting procedures.
[102] Cable owners tend to view this as inconsistent with their rights and responsibilities under the United Nations Convention on the Law of the Sea (1982) ("UNCLOS").
[103] This is a reliability concern because this practice often increases the duration of repair times, increases maintenance costs, and destabilizes the investment environment for this critical infrastructure: if nation-states can impose such mandates at will, the rights of cable owners are uncertain.
[104] October 1982, www.un.org/Depts/los/convention_agreements/convention_overview_convention.htm.
[105] Appendix E.
[106] A continental shelf is the undersea extension of a continent, which can extend out for many miles into sea.
[107] UNCLOS Article 57, Submarine cables and pipelines on the continental shelf. See Appendix E.

85. **Freedom of the High Seas.** Freedoms spelled out for all nation-states on the high seas specifically include one to lay undersea cables, in addition to those for navigation, over flight, constructing artificial islands, fishing and scientific research.[108]

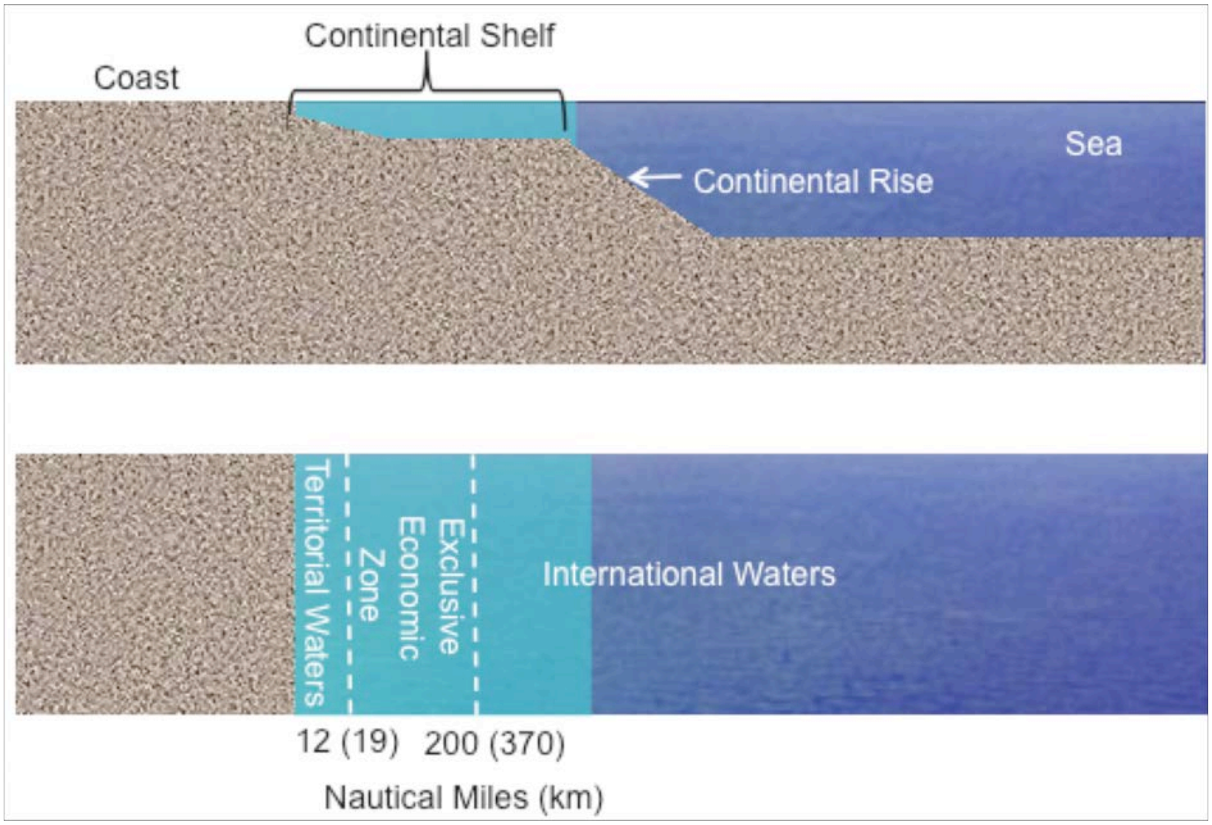

Figure 30. The Continental Shelf and Water Zones.

86. **Intelligence Eavesdropping.** The switch from metallic to fiber optic cable made the interception of traffic over undersea cables much more difficult.

87. **A Shot Across the Bows.** Hostilities on the High Seas are an increasing concern for undersea cable repair ship operators, their crews and other stakeholders.

88. **International Infrastructure.** Many nation-states classify their international undersea communications cable assets as "critical national infrastructure." However, these cable systems are really *international.*[109]

89. **A History of Importance.** Undersea communications cables have been protected with international law since the *International Convention for the Protection of Submarine Cables* of 1884.

[108] UNCLOS Article 87, Freedom of the high seas, Article 112, Right to lay submarine cable and pipelines. See Appendix E.
[109] Burnett, Douglas, *International Telecommunication Cable Repair Under UNCLOS.*

90. **It Needs Some Teeth.** Willing or negligence-caused damage to undersea cable is a punishable offense, though few nation-states have effective legislation to support the international law.[110]

91. **Keep Your Hands to Yourself.** Parties that damage a neighboring undersea cable when deploying or maintaining their own cable are responsible for the cost of the damages they cause.[111]

92. **Anchors Away!** Nation-states are to recognize when a ship has sacrificed an anchor or fishing equipment in order to avoid damaging an undersea cable.[112]

93. **Seabed Ownership.** Part XI of the UNCLOS provides for the assignment of mineral rights outside of the EEZs. UNCLOS set up the International Seabed Authority, an intergovernmental organization that controls mineral activities in international seabed areas.[113]

94. **U.S. Not On Board.** The United States has signed, but not ratified, the United Nations Convention on the Law of the Sea. Objections to the role of the ISA have been cited as impeding ratification. The United States is the only major maritime power to not ratify the treaty.

95. **Mining the Floor.** The International Seabed Authority is experiencing a dramatically heightened interest in the mining of seafloor minerals.[114] This is significant from a reliability perspective as activity on the sea floor can have harmful repercussions on cable integrity.

96. **Controlled Approaches.** Some nation-states have established special zones for communications cables. Advocates emphasize the benefits that the clarity of designated locations provides for protecting cables through restricted access. Critics raise concerns of tighter physical concentration and of heightened awareness of the critical infrastructure locations.

97. **Good Housekeeping?** Policies within nation-state governments are not coordinated. Examples include the domains of security, regulation, commerce, environment, transportation and windmill and mining and fishing activities.

98. **Battened Down the Hatches.** Those who may be most aware of the concerns from their nation-state's security perspective are also those whose responsibilities are highly aligned with specific nation-state security interests. These individuals are seldom enabled to engage international parties to discuss their concerns and propose

[110] UNCLOS Article 113, Breaking or injury of a submarine cable or pipeline. See Appendix E.
[111] UNCLOS Article 114, Breaking or injury by owners of a submarine cable or pipeline of another submarine cable or pipeline. See Appendix E.
[112] UNCLOS Article 115, Indemnity for loss incurred in avoiding injury to a submarine cable or pipeline. See Appendix E.
[113] The ISA is based in Kingston, Jamaica. www.isa.org.jm.
[114] The International Seabed Authority is an autonomous international organization established under the 1982 United Nations Convention on the Law of the Sea and the 1994 Agreement relating to the Implementation of Part XI of the United Nations Convention on the Law of the Sea. www.isa.org.jm

cooperative measures to protect GUCCI. Track II discussions are a possible avenue for international critical infrastructure protection.

99. **A Sea Change.** The deployment of new alternative cable routes to avoid several GUCCI geographic chokepoints would require international ASPR breakthroughs.

100. **Eating Dust**. Relative to the growth in stakeholder needs and the advances in technology, progress in essential complimentary international ASPR is not keeping pace.[115]

[115] 81% of the participants of the EWI Worldwide Security Conference 7, Multilateral Cybersecurity Consultation indicated that *"the current level of international cooperation in cyber space is far, far behind where it needs to be."* Brussels, February 2010.

5. RECOMMENDATIONS

The ROGUCCI process led to the development of twelve Recommendations. Each of these Recommendations is actionable and, if implemented, would improve the reliability of global communications infrastructure. These Recommendations were developed based on international stakeholder perspectives from six continents, the insights captured from the 100 Key Observations and expertise from across the eight ingredients of communications infrastructure. In addition, each Recommendation was reviewed and supported by stakeholders who are vitally dependent on GUCCI.

This section presents each of the twelve Recommendations along with supporting material, which includes a concise statement of purpose, brief background, review of benefits achieved with The Recommendation's implementation, required commitments, alternatives and their consequences, suggested next steps and measures of success. Because these recommendations are intended to mobilize individuals and organizations in effective and coordinated action, the articulation of this surrounding guidance is considered indispensible in realizing the sought after reliability improvements.

Leadership Posture for Recommendation Implementation

These Recommendations require the active support of the stakeholders, governments and the private sector. Table 7 provides an overview of the primary leadership role(s) for each Recommendation. Each Recommendation was fashioned with diligent attention to many important interests and factors, such as respecting nation-state sovereignty and security interests, recognizing the long-term planning required to deploy an international long-haul cable system, dealing with the harsh and isolated environment that hosts undersea cables, acknowledging the public's profound unawareness of its dependence on this infrastructure, and many others. Primary leadership roles were identified based on these factors, interests and competencies. A noteworthy observation here is that primary and supporting leadership roles are shared among stakeholders, governments and the private sector. This is important because upholding the reliability of the world's communications infrastructure is a shared responsibility, and the critical principals need to respect and support the distinct roles of each other, as well as fulfill their own.

Another noteworthy observation from Table 7 is that the private sector is more often the primary leader than are stakeholders or governments. To be clear, given the relative constraints for governments to forge agreements, the leadership of the private sector is imperative.

The Recommendations are deliberately written at the level of specificity presented. For example, while it is apparent that there are organizations possibly well suited for implementing certain aspects of a given recommendation, restraint has been used to avoid naming specific organizations as candidates. This is done in order to preserve an open opportunity for others to take initiative and serve as leaders. There is a lot of work to be done. All available, qualified resources are needed. Thus, other than by broad role (i.e. private sector, stakeholder, government), the potential sources of support are quite open. Other examples of targeted specificity are seen by the focus on the heart of required commitments, analysis of alternative approaches and the brevity of the measures of success.

The ROGUCCI web site has been designated as a place to track ongoing progress of recommendation implementation.

Table 7. Leadership Posture for Recommendation Implementation

	ROGUCCI Recommendations	Private Sector	Stakeholders	Governments
1	Rudimentary Geographic Diversity for Global Infrastructure	1	1	1
2	Prioritization for Timely Cable Repairs	1	2	1
3	Preparedness for Hostile Maritime Crisis	2	0	1
4	Best Practices and Trusted Information Sharing	1	2	2
5	New International Governance	1	2	2
6	International Communications Infrastructure Standard for the Financial Sector	2	1	2
7	Measurements for Stakeholder Due Diligence	1	2	0
8	Improved Cable Protection Agreements, Standards, Policies and Regulations (ASPR)	2	0	1*
9	Government Inter-Agency Coordination for Undersea Cable Infrastructure	2	0	1*
10	Education and Awareness of GUCCI Critical Role	1	2	2
11	Mechanisms for Handling Overload Demand	1	2	1
12	Recognize Catastrophic GUCCI Loss	1	2	2

*includes nation-state and state or provincial levels

KEY	
Primary Leadership Role	1
Active Supporting Leadership Role	2
Not Applicable	0

Recommendation Impact

The Recommendations deal with the full range of challenges: the normal non-crisis state, the crisis state, and the crisis response state. Figure 31 provides a high level overview of the relationships of The Recommendations to these three states. Here a timeline is used to show the progressive situations of normal operation, crisis, recovery and return to normal operation. The reliability of GUCCI concerns each of these situations, and therefore The Recommendations span the continuum.

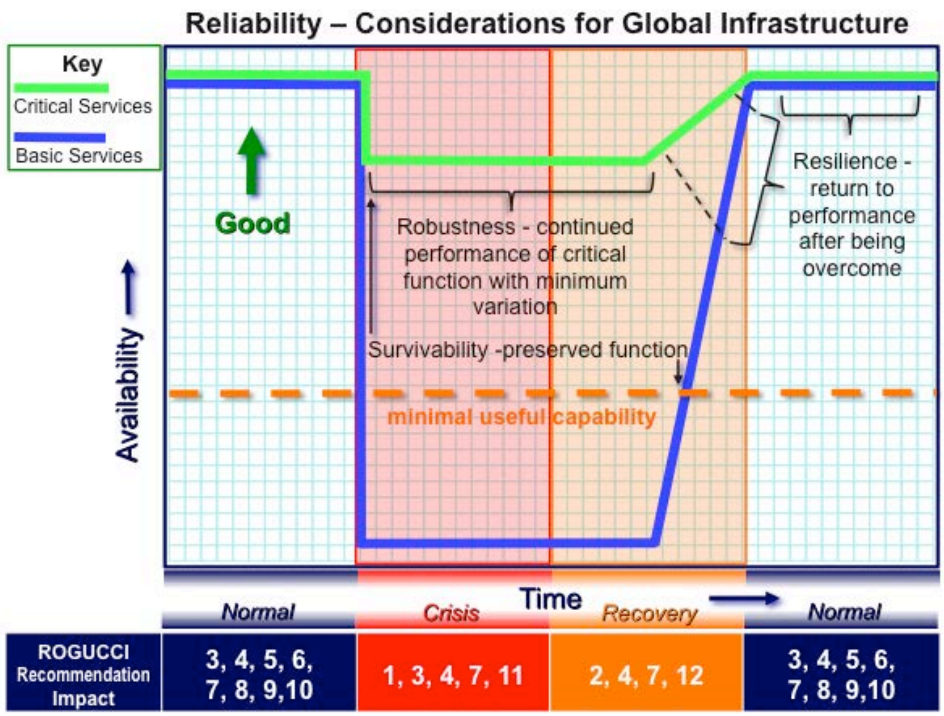

Figure 31. Recommendation Impact Across Time Continuum

Continuing with reference to Figure 31, the following is a brief summary of the impact of each Recommendation's implementation.

- Recommendation 1, *Rudimentary Geographic Diversity for Global Infrastructure*, decisively reduces the impact of the most severe multiple cable cuts that could be experienced.

- Recommendation 2, *Prioritization for Timely Cable Repairs*, reduces the time associated with restoring service after individual disruptive events, and would have very strong overall improvement on combined GUCCI downtime.

- Recommendation 3, *Preparedness for Hostile Maritime Crisis*, can help avoid a disruptive attack event and also provide critical management during a crisis that may occur.

- Recommendation 4, *Best Practices and Trusted Information Sharing*, enables higher levels of reliability in normal conditions and also provides support for crisis and crisis recovery situations.

- Recommendation 5, *New International Governance*, enables higher levels of reliability in normal conditions.

- Recommendation 6, *International Communications Infrastructure Standard for the Financial Sector*, provides the financial sector with enhanced capabilities to manage its critical interests during normal conditions.

- Recommendation 7, *Measurements for Stakeholder Due Diligence*, will provide much needed advances in understanding GUCCI performance during normal, crisis and crisis recovery periods.

- Recommendation 8, *Improved Cable Protection Agreements, Standards, Policies and Regulations (ASPR)*, will keep GUCCI in normal conditions by providing countermeasures to prevent some of the most common forms of crises.

- Recommendation 9, *Government Inter-Agency Coordination for Undersea Cable Infrastructure*, will assist in optimizing the conditions that support normal conditions.

- Recommendation 10, *Education and Awareness of GUCCI Critical Role*, will elevate the level of understanding of how important the normal conditions are to the health of governments, commerce and society.

- Recommendation 11, *Mechanisms for Handling Overload Demand*, will provide robustness by enabling the most critical traffic to be carried to its destination during periods of crisis.

- Recommendation 12, *Recognize GUCCI Catastrophic Loss as a Grand Challenge*, will commence what is expected to be a long journey toward solutions that will enable a more acceptable crisis recovery from a catastrophic worldwide, or wide regional, loss of GUCCI.

Relationship Between the Key Observations and Recommendations

The 100 Key Observations played a key role in the formulation of The Recommendations. After analyzing over 10,000 data points, most of these Key Observation were selected for their supportive role in the formation of The Recommendations.[116] Insights gleaned were prioritized based on their potential for addressing the reliability, robustness, resilience and security of GUCCI. Specific Key Observations references are integrated throughout the presentation of each Recommendation.

[116] Some Observations were included for their purely tutorial value.

5.1 Rudimentary Geographic Diversity for Global Infrastructure

Purpose

This Recommendation addresses the issue of *how to significantly improve the reliability of GUCCI by addressing unwanted points of concentration through the use of geographically diverse routes.*

Background

The world's undersea communications cable infrastructure performs at a level of reliability such that its availability and operation are taken for granted by countless users.[117] However, the dramatically increasing dependence upon this infrastructure evokes a sense that ever-increasing diligence is needed to ensure its reliability performance is commensurate with this dependence.[118] When designing and implementing highly reliable systems, a fundamental principle of reliability engineering is to avoid single points or modes of failure.[119] Redundancy and diversity are design techniques used to prevent any single failure causing a system-wide failure. This is because the statistical likelihood of one failure is typically several orders of magnitude higher than for two or more failures occurring simultaneously.[120] [121] The fundamental principle of avoiding single points of failure is compromised in the world's global undersea communications cable infrastructure due to the aggregation of cables at certain geographic "choke points".[122] These locations include the Luzon Strait,[123] the 'Suez Canal-Red Sea-Mandab Strait' passage,[124] and the Strait of Malacca,[125] among others.[126] Single points of failure are latent design weaknesses, whether or not they are ever exposed.[127] [128] Recent history provides instances where this susceptibility has been exploited.[129]

The ideal GUCCI topology would be a mesh network with deliberate geographic diversity that wraps a highly interconnected web around the planet. Contributing factors to the current situation include real and perceived geographic and nation-state political barriers to preventing private sector investment in alternate routes to avoid existing choke points.[130] Hindrances include initial resistance to explore and invest in these locations, and then uncertainty regarding access to these cables for maintenance. In addition, economic incentives motivate undersea network installations to re-use existing paths.[131] [132]

[117] Key Observation 42, Highly Reliable Components, Section 4.2.
[118] Key Observation 2, More Bandwidth ≠ More Resilience, Section 4.1.
[119] Can be abbreviated as SPOF, SMOF.
[120] Context is for a system built for high reliability applications.
[121] Key Observation 52, SPOFs, Section 4.2.
[122] Even if redundant systems are deployed in such a way that a common aspect is aggregated in a common area, then a single point of failure is created.
[123] The body of water that connects the Philippine Sea of the western Pacific Ocean to the South China Sea, between Taiwan and Luzon in the Philippines. The strait is about 250 km (155 miles) wide.
[124] The Mandab Strait, also, Bab-el-Mandeb, Bab el Mandab, Bab al Mandab, or Bab al Mandeb meaning "Gate of Tears" in Arabic (باب المندب), is the strait separating the continents of Asia (at Yemen on the Arabian Peninsula) and Africa (at Djibouti, north of Somalia on the Horn of Africa), and connecting the Red Sea to the Indian Ocean (Gulf of Aden). The width of the Strait is about 30 km (18 miles).
[125] The Strait of Malacca is a narrow, 805 km (500 mile) stretch of water between Peninsular Malaysia (West Malaysia) and the Indonesian island of Sumatra; the Strait is 64 km (40 miles) wide at its narrowest point.
[126] Key Observation 8, Pacific Rim Leadership, Section 4.1.
[127] Key Observation 50, Looking Backwards, Section 4.2.
[128] Key Observation 51, Intrinsic Vulnerability Approach, Section 4.2.
[129] Recent instances of multiple cables being damaged in geographically concentrated cable pathways include the Hengchun Earthquake (December 2006), Middle East (January-February 2008), Alexandria, Egypt (December 2008) and the Typhoon Morakat (August, 2009). See Appendix A for a description of these events.
[130] Key Observation 78, Geo-politics, Section 4.4.
[131] Key Observation 72, The Road More Travelled, Section 4.3.

Overland alternatives have always been a possible solution, however, such routes also have challenges such as accessibility for initial deployment and ongoing maintenance.[133]

Recommendation 1
Stakeholders for highly reliable and resilient international communications should actively promote the deployment of geographically separate cable paths to avoid current single points of failure, by serving as advocates to the nation-states controlling the lands and waters for potential alternative, diverse paths.

Required Commitment

To sustain the viability of The Recommendation, stakeholders, governments and the private sector must be committed to defined courses. Specifically,

- ☐ Stakeholders must commit to a course of advocacy to ensure that effective articulation of the geographic concentration risk is understood by the appropriate governments.[134]
- ☐ International policy change agents must effectively frame the interests for decision makers and mobilize resources.[135]
- ☐ Nation-state governments must provide access to investors and provide assurances for timely ongoing maintenance.
- ☐ Investors must build out new fiber cable systems in routes providing new geographic diversity.

Benefits of Rudimentary Geographic Diversity for Global Infrastructure

When implemented, The Recommendation will provide more reliable global connectivity. This improved reliability will benefit both far separated continents whose connectivity depends on existing choke point passage, as well as the regions with the choke points. The international financial services sector will benefit from improved economic stability. Countless private enterprises of all sizes will benefit from enhanced business continuity. Governments will benefit from enhanced continuity of operations for essential services. International media outlets will be served with improved resilience when covering crises. Individuals will benefit by the improved availability of global connectivity.

If implemented correctly, the new routes will be of a distance similar to - or shorter than - existing routes, so as to preserve the low latency transport required by time-sensitive users, such as the financial services sector. Shorter routes would provide the added benefit of reduced latency and be thus more competitive for financial markets.

[132] Key Observation 73, Business Appetite, Section 4.3.
[133] The most common cause of terrestrial network outages in the U.S. has traditionally been cable cuts per ATIS Network Reliability Steering Committee (NRSC), www.atis.org.
[134] Key Observation 20, Resigned to Learn the Hard Way, Section 4.1.
[135] Key Observation 99, A Sea Change, Section 4.4.

Alternative Approaches and Their Consequences

Alternatives to this approach include the following:

- Keep the issue quiet . . . *resulting in eventual exposure through natural or man-made forces, but with the impact being greater due to increased dependence on GUCCI as time goes by.*[136] [137]
- Discourage use and dependence on global connectivity . . . *would be cause for profound disadvantage to a nation-state in terms of technological and economic development.*[138]
- Maintain the current course . . . *passively promoting increased global dependence on global infrastructure with latent design deficiencies, the anticipated ramifications being higher likelihood of catastrophic loss of global or regional connectivity.*[139]

Next Steps

Suggested next steps to generate momentum toward the implementation of The Recommendation include:

1-1. Private and public sector stakeholders should establish a guiding coalition to actively raise awareness of existing SPOF concerns and advocate deployment of geographic diversity for cable routes at existing choke points. A proven global policy change agent should champion this initiative.

1-2. Financial sector and other stakeholders should articulate their need for reduced operational risk through geographic diversity around existing infrastructure choke points.

1-3. Governments with sovereignty in regions with existing GUCCI SPOF concerns should attract investors by providing assurances regarding access for deployment and ongoing maintenance as well as clarity around private sector ownership rights of deployed infrastructure.

1-4. Rudimentary geographic diversity is provided at existing GUCCI choke points with the deployment of additional communications cables taking alternative routes.

Measures of Success

The successful implementation of The Recommendation can be gauged by the following measures:

Geographic diversity provided: Existing undersea cable infrastructure choke points are avoided through the deployment of cables in physically diverse routes.

Latency-competitive routes provided: The routes designated as alternatives for the existing choke points are of similar or shorter distance so that they avoid unacceptable payload latency.

Improved availability of global communications infrastructure: The availability of the world's communications infrastructure is improved as calculated from appropriate models.

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[136] One approach to addressing this infrastructure design concern is to reduce awareness in order to limit its exposure to malicious agents. The desired benefits of this approach would be minimal, as information regarding cable path routes and points of concentration are already in the public domain. In addition, the consequences of reducing awareness of this concern will compete with the need for broad global awareness and the need for cooperative action.

[137] Gambetta, Diego, and Hertog, Steffen, *Engineers of Jihad*, Sociology Working Papers, Department of Sociology, University of Oxford, 2007. This paper documents that a significant number of terrorists have advanced technical training. Thus they are capable of accessing the existing public domain information and understanding the infrastructure implications.

[138] In 2007, the total transaction volume of e-commerce in China exceeded 2 T Yuan, a 90% growth over the previous year. E-commerce is forecast to be the main medium of commerce and about 70% of trade in 10 years. China Economic Net, November 2008.

[139] Key Observation 100, Eating Dust, Section 4.4.

5.2 Prioritization for Timely Cable Repairs

Purpose

The Recommendation addresses the issue of *how to significantly reduce the average time needed to restore service after cable damage. This can be done by addressing the lengthy approval process for cable repair vessels to gain access to sovereign waters.*

Background

Damaged undersea cable repairs have extended durations for three primary reasons: weather, contention for limited resources and government permitting processes for access to sovereign waters.[140] [141] [142] The first is outside of human control and the second is discussed elsewhere in The Report. The third reason is addressed here. Unlike other challenges for improving the reliability of GUCCI that deal with hard limitations in physics and geography, very long distances, and outdoor and undersea environments, improving the time needed to complete a process is very much a soft and controllable parameter.

The repair of a damaged undersea communications cable is a process that involves coordination between the cable system owner, a specialized repair vessel operator and the nation-state government in whose waters the repair operation needs to be performed.[143] [144] Because of variations across nation-state governments' policies and procedures that grant access for repair operations, there is wide variation in permitting approval times – from 24 hours to well over 2 months. Despite the greatly increasing dependence on this infrastructure and resulting negative impact associated with any downtime, there has been no meaningful change in years. On one hand, there are governments whose process is proactive and streamlined. In these cases, speedy restoration of service has been prioritized and coordination planning for responses to anticipated outages includes pre-approval for repair operations in designated waters. Such coordination and planning keeps the approval process on the order of only days.[145] On the other hand, there are governments whose approval approach is reactive, uncoordinated among divisions, or otherwise ineffective in prioritizing the restoration of service over damaged cables.[146] These cases are typified by information being requested during the approval process that could have been provided in advance of an outage, slow and bureaucratic interactions between government agencies or ministries, and a general unawareness of how the approval for access into waters is a priority – even though the government may at that very time be experiencing severe negative affects from the outage.[147] [148] In these cases, outage durations are unnecessarily extended by additional weeks.[149]

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[140] Key Observation 74, Specialized Cable Ships, Section 4.3.
[141] Key Observation 80, Confusing Boundaries, Section 4.4.
[142] Key Observation 81, Need to Go the "Extra Mile", Section 4.4.
[143] There are three possible situations: no permit required, permit required in territorial waters (typically 12 nautical miles), permit required in disputed territorial waters.
[144] If different from the government of the territorial sea, the government of the coastal area hosting the landing station is an additional entity needing to be engaged.
[145] Key Observation 77, Maintenance Access, Section 4.3.
[146] Key Observation 79, Paperwork, Section 4.3.
[147] Repair vessel owners have been required to provide annual reports on their companies' business as part of one lengthy approval process; this is information that could have been requested and provided well ahead of an outage.
[148] Even in situations where all agencies of a government agree with approval for access, the carrying out of routine administrative protocols introduce weeks of delays.
[149] It is recognized that a nation-state government may need time to perform forensic analysis of a cable's damage for its security interests; though the time required for this activity is not as long as the delay durations here referenced. Additional security concerns include cable repair ships performing espionage or surveying missions.

Regarding the special case of disputed territorial waters, the undersea cable industry continues to expend considerable effort to promote ratification of the UNCLOS as a means of establishing international laws protecting the rights of cable owners in international waters.[150] The industry is encouraged that the UNCLOS provides special status to undersea communications cables, but also recognizes that confusion is caused by the differences between legal regimes under the UNCLOS territorial seas, Exclusive Economic Zone (EEZs) and Continental Shelves with regard to submarine cables.[151] [152] [153]

Very long duration outages are a major concern regarding the reliability of GUCCI because they contribute significantly to overall widespread downtime or impairment. In addition, these long duration outages should be a major concern for the economic stability of an established or emerging nation-state, as its business, financial transactions and many other international connectivity-dependent functions are lost or severely impaired.[154]

Recommendation 2
Nation-state governments should implement policies and procedures to provide timely approval to authorized cable ships seeking permission to repair damaged undersea communications cables.

Required Commitment

To sustain the viability of The Recommendation, stakeholders, governments and the private sector must be committed to defined courses. Specifically,

- ☐ Nation-state governments must conduct advance planning in anticipation of cable damage.
- ☐ Nation-state governments must prioritize the restoration of undersea communications cables by committing to providing an efficient and appropriately-speedy process for granting authorized repair vessels access to their sovereign waters.[155]
- ☐ Cable ship operators and cable infrastructure owners must cooperate with government requirements for information, onboard inspections, escorts and other requests, particularly when opportunities for pro-active engagement are presented.
- ☐ Nation-state governments must be willing to compare themselves to best-in-class benchmarks for efficient permitting time durations.

[150] As of October 2009 there are 157 signatures.
[151] Key Observations 82, UNCLOS, and 83, EEZ, Section 4.4.
[152] China Institute for Marine Affairs (CIMA) and Center for Ocean Laws and Policy (COLP) Regional Workshop on Submarine Cables Workshop Report, Beijing, PR China, May 2009.
[153] The EEZ is a seazone where a nation-state has rights regarding exploration and use of marine resources (UNCLOS Part V Article 55). The EEZ is 200 nautical miles (370 km) from the coastline. Rights associated with the continental shelf extend to 350 nautical miles (650 km) from the coastline (Article 76).
[154] Since the infrastructure may cross many borders, government guarantees supporting infrastructure reliability are required, including policies ensuring that providers will always have timely access to restore a failed part of a system. *Resilient International Telecommunications Guidelines for the Financial Service Sector,* Pacine, Wayne and Callahan, Roger, Financial Service Sector Coordinating Council www.fsscc.org, 2009.
[155] Key Observation 100, Eating Dust, Section 4.4.

Benefits of Prioritization for Timely Cable Repairs

When implemented, The Recommendation will provide more reliable global connectivity by reducing both the frequency of outages and the average amount of time damaged cables are out of service while awaiting repair. The *frequency* is reduced as repairs can be performed more quickly for system faults that have the system utilizing its back-up facilities, but that have not yet resulted in an outage. The longer the delay in repairing the primary facilities, the more likely a service outage will occur.[156] The implementation of The Recommendation will also reduce the *duration* by similarly reducing the repair interval time of outages.

Another benefit of the implementation of The Recommendation is that it will increase awareness within governments regarding the critical role of GUCCI. In addition, the carrying out of The Recommendation will foster cooperation between governments and private sector partners.

Alternatives Approaches and Their Consequences

Alternatives to this approach include the following:

- Focus all efforts solely on endorsing ratification of the Law of the Sea . . . *forfeiting achievable progress with less demanding instruments.*
- Cable ships enter waters to begin repairs prior to permits being issued . . . *placing crews and the vessels at risk, potentially creating an incident that is interpreted as challenging nation-state sovereignty.*
- Maintain status quo . . . *continuing to accept critical international infrastructure outages of longer durations than are necessary, with intensifying impact given the increasing global dependence.*

Next Steps

Suggested next steps to generate momentum toward the implementation of The Recommendation include:

2-1. Nation-state governments with best-in-class performance in facilitating speedy repair of damaged cables should be identified and encouraged to provide their best practices to serve as references for other governments to consider.[157]

2-2. Nation-state governments lacking the ability to facilitate timely authorized access to their sovereign waters should develop policies and procedures that will enable them to achieve performance comparable to international best-in-class benchmarks.

2-3. Cable owners and repair vessel operators should engage governments where there are new opportunities to build pro-active permitting procedures.

[156] Key Observation 34, Out on *Two* Strikes, Section 4.2.
[157] e.g., At the time of cable system installation, the cable system operator should work with the authorizing government on permitting procedures for future access for repairing anticipated cable damage. Ideally, the agreed procedure would include some type of advance permitting arrangements. This Best Practice was shared at the ROGUCCI Global Summit, Dubai, October 2009.

Measures of Success

The successful implementation of The Recommendation can be gauged by the following measures:

Improved cooperation: Pro-active planning between private sector and governments regarding expectations of each critical party and associated estimated time intervals for completion.[158]

Reduced outage durations: The duration of damaged cable-caused outages is reduced in areas where there are currently protracted durations due to slow permitting procedures.

Benchmark performance awareness: Governments measure their permitting approval procedures against internationally recognized best-in-class performance benchmarks.

[158] e.g., some sort of pre-approval arrangement for cable ships operating within certain regions.

5.3 Preparedness for Hostile Maritime Crises

Purpose

The Recommendation addresses the issue of how to provide a mechanism for rapid response to hostile activities against international communications cables or the industry's specialized cable ships by undertaking coordination, planning, and other emergency preparedness activities.

Background

A basic exposure of undersea cables and cable ships is simply that they can be identified and located.[159] [160] There are a number of concerns that arise from this ever-present susceptibility.

For example, one of the major causes of outages in Southeast Asia during the past decade has been the theft of cables for interest in their metallic content for scrap resale.[161] A corresponding outage trend was observed with terrestrial networks during this time frame.[162] This trend seems to have passed its peak for now, being correlated to the previous market highs for certain metals. Another concern is the new wave of high seas piracy. Undersea communications cable repair ships are highly specialized vessels that have a vital role in the resilience of GUCCI.[163] Pirate attacks are on the order of hundreds worldwide, and increasing at an annual rate of about 200%.[164] [165] These vessels represent a limited resource and their loss or damage could contribute to significantly longer outage repair times.[166] Unfortunately both undersea cable routes and pirate activities seem to be common at geographic chokepoints. As an example of this, the hottest bed for pirate attacks in the world is the water off the Somali coast in the Gulf of Aden region.[167] This is the same stretch of water that hosts undersea cable routes that connect Europe to Asia. The typical motivation of pirates is different than that of terrorists. Pirates are motivated to gain a ransom and so their harm is limited to the threats they pose to the personnel, the vessel and the infrastructure through extended outage durations, should the vessel be unavailable. Conversely, other malicious actors - such as terrorists - could target and misuse these specialized vessels for harm against undersea infrastructure.

While most vessels will have some sort of security program, today's sophisticated pirates can likely outmatch such defenses, leaving crews, vessels and the infrastructure in danger. In light of the industry's inherent exposure to malicious activity, enhanced preparedness is needed.

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[159] Appendix A outlines the extensive information readily available in the public domain.
[160] Key Observation 49, Visibility Means Accessibility, Section 4.2.
[161] Thieves may be searching for metallic cables, not able to distinguish fiber optic cables.
[162] The Network Reliability Steering Committee (NRSC) special study on malicious activities is documented in the *NRSC 2006-2007 Bienniel Report*, pp 24-25, ATIS, August 2008, pages 24-25. The Report documents industry consensus expert guidance that was developed to deter theft of cables.
[163] Key Observation 74, Specialized Cable Ships, Section 4.3.
[164] International Maritime Bureau, July, 2009.
[165] Key Observation 87, A Shot Across the Bows, Section 4.4.
[166] Key Observation 18, Waiting for My Ship to Come In, Section 4.1.
[167] "Somali pirates carried out a record number of attacks and hijackings in 2009, despite the deployment of international warships to thwart them and a United Nations Security Council resolution to bring the fight against them to shore." The Piracy Reporting Center of the International Maritime Bureau reported counted that pirates operating across the Gulf of Aden and along the coast of Somalia had attacked 214 vessels so far this year, resulting in 47 hijackings, a 200% increase from 2007. *Record Number of Pirate Attacks in 2009*, New York Times, December 29, 2009.

Recommendation 3
Nation-state governments should cooperate with each other and private sector undersea communications cable infrastructure owners and operators to develop maritime crisis preparedness plans that would protect communications cable vessels that are vital to the operation of global undersea communications cable infrastructure.

Required Commitment

To sustain the viability of The Recommendation, nation-state governments and the private sector must be committed to defined courses. Specifically,

- ☐ Nation-state governments must cooperate in establishing intergovernmental agreements, participating in planning, and being part of periodic simulated crisis exercises.
- ☐ Owners of cable ships must support effective planning and exercises by making vessels and critical personnel available.
- ☐ Nation-state governments and cable ship owners must establish agreements on cooperation procedures for maritime crisis response.

Benefits of Preparedness for International Crises

The benefits of implementation of The Recommendation will include improved crisis readiness. Effective crisis response will translate into avoided downtime, thus strengthening GUCCI reliability. In addition, another advantage will be better awareness of the role of undersea cable infrastructure and cable ships among nation-state security stakeholders. Regional cooperation in crisis preparedness will build a foundation for more advanced discussions in related areas such as general cable protection.

Alternative Approaches and Their Consequences

Alternatives to this approach include the following:

- Decide to leave private sector to defend itself alone . . . *increasing likelihood of harm to crew, vessels, and cable infrastructure.*
- Do nothing, waiting for an event to occur and then react during this time . . . *forfeiting advantages that could have been achieved with advance planning and coordination.*

Next Steps

Suggested next steps to generate momentum toward the implementation of The Recommendation include:

3-1. Nation-states and cable system operators should convene regionally to conduct a joint threat assessment and develop plans for responding to a hostile attack against cable infrastructure or cable ships.

3-2. Nation-state governments and cable system operators should implement the crisis preparedness plans developed, including 24x7 points of contact.[168]

3-3. Nation-state governments and cable system operators should design and conduct crisis response exercises to evaluate the effectiveness of their plans and to provide practice for the organizations involved.

Measures of Success

The successful implementation of The Recommendation can be gauged by the following measures:

Government-private sector coordination: Jointly developed plans are implemented.

Emergency contact points: Government and private sector interfaces are established and operational.

Crisis response: Maritime crises are handled safely and effectively.

[168] An important consideration is the need for modes of communications that are non-undersea cable-based, given the scenari os that are being addressed. Thus satellite phones should be considered for international communications.

5.4 Best Practices and Trusted Information Sharing

Purpose

The Recommendation addresses the need to share sensitive information among industry and government stakeholders, within a trusted environment, enabling all participants to benefit from this shared body of knowledge that is essential to optimize network reliability and resilience.

Background

The scope of undersea cable infrastructure reliability is vast. Whether viewed as protecting the integrity of hundreds of thousands of kilometers of cable, or from the meticulous diligence required for the exhaustive extent of the eight ingredients, it is a very big job. However, it can also be a subtle and delicate topic. The transmission of terabits is done in complete silence through fiber strands as thin as a human hair.[169] Another of the more quiet sides of GUCCI is the sensitive nature of some of its business. Outages are a delicate topic because they can reflect negatively on a business reputation resulting in disadvantageous marketplace differentiation and reduced revenues.[170] Other international infrastructure protection information can be nation-state security, where topics may include security compromises that have happened or concerns that are insufficiently prepared for.[171] While the needs for protecting sensitive information are quite clear, there are equally compelling reasons for ensuring that industry peers are well informed, as better awareness can be critical in strategies for protection and reliability assurance. This information sharing is needed on an international basis – particularly for GUCCI, as inter-continental undersea cables are by definition international critical infrastructure.

Precedents for effective information sharing in trusted environments are well established within the communications industry.[172] In today's world of many suppliers, owners and operators, optimum infrastructure protection cannot be provided without effective information sharing.[173]

A number of organizations have agendas and active memberships that seek to develop common best practices and address issues impeding the business of planning, installation and maintenance of undersea cables.[174] The memberships of these communities have developed a commendable level of trust. However their remits do not facilitate the resolution of the broader concerns of global resilience voiced by industry peers and stakeholder participants of the ROGUCCI study group. Information exchanges are specifically designed to encourage and facilitate this kind of debate and to develop consensus solutions, which transcend barriers presented by commercial or political interests. With such a huge scope however,

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[169] Key Observation 35, As Thin As Your Hair, Section 4.2.
[170] Key Observation 66, Competitive Differentiation, Section 4.3.
[171] A useful point of guidance posted in the ROGUCCI web forum. An example in the cyber security space is consider when a government agency has information about 'the Who', 'the Why', 'the What', 'the When' and 'the How' for a specific cyber attack. Naturally this information is very sensitive. However the technical practitioner may be only interested in 'the How'. By negotiating a limited exchange of information about 'the How' a compromise can be found to provide more timely and accurate exchange of information whilst still protecting sensitivities. Peter Brouggy, January 2010.
[172] The ATIS Network Reliability Steering Committee (NRSC) has fostered industry cooperation that has improved the reliability of the U.S. public networks. The NRSC has operated as a trusted information sharing environment to share analysis insights on outages and develop voluntary, expert best practices for over 15 years (www.atis.org/nrsc). Other references include the WARP (www.warp.gov.uk/TrustedSharing.htm) approach that has been deployed in numerous sectors. The European Network and Information Security Agency (ENISA) is a recently re-invented approach (www.enisa.europa.eu).
[173] Rauscher, Karl, *European Commission Availability and Robustness of Electronic Communications Infrastructure (ARECI) Report*, March 2007, page 102.
[174] These include the International Cable Protection Committee, the Submarine Cable Improvement Group, and the International Jointing Consortium.

some means of partitioning information exchange is needed to bound discussions in order to ensure relevance to all participants, yet remain sufficiently flexible to allow broad ranging and interdisciplinary solutions. For example, those who are concerned with the mechanisms for protecting the physical undersea cable sections will, in general, deal with different people and policies than those who are concerned with peering arrangements. Yet both aspects have been shown to influence traffic behavior in the event of a major failure.

With the enormous challenge of protecting and advancing the reliability of GUCCI, the private sector needs every advantage it can get. Given the choice between the status quo, or a trusted information sharing environment where industry and nation-state stakeholders could have the combined intelligence of the industry, the clear choice is the later.[175]

Recommendation 4
The private sector should establish formal means for sharing information that can improve the protection and rapid restoration of undersea communications cable infrastructure.

Required Commitment

To sustain the viability of The Recommendation, the private sector and nation-state governments must be committed to defined courses. Specifically,

- Private sector companies that own and operate undersea communications infrastructure must jointly establish a trusted environment for sharing information to improve the protection and rapid restoration of GUCCI.
- The private sector must be willing to share threat and outage information in a trusted environment within the industry for the common good.
- Nation-state governments must be willing to share threat and other sensitive information with owners and operators of GUCCI and safeguard information provided by the industry.
- Nation-state governments must be willing to share information that will improve the protection and rapid restoration of critical infrastructure with other nation-states as well as the owners and operators of that infrastructure within the other nation-states.

Benefits of New International Governance

Knowledge is power. Sharing information among owners, operators and the governments whose constituencies depend on that critical infrastructure, provides decision makers with additional knowledge and insights to help them prepare for, and react to, trends or threats. The sharing of sensitive information will only occur and flourish in an environment characterized by openness, concern for the common good, and most of all, trust.

The perceived benefits of establishing information exchanges include the comprehensive capture of customer requirements, a coherent service provision to customers worldwide, the preservation of commercial confidentiality, the development of 'common good' consensus outside of commercial and political arenas and the reduction of human barriers to progress.

[175] Key Observation 39, Not a Role Model *Yet,* Section 4.2.

Alternative Approaches and Their Consequences

Alternatives to this approach include the following:

- Industry stakeholders sharing only with selected partners . . . *resulting in fragmented sharing and response to attacks, and various providers of critical international infrastructure being left uninformed.*
- Critical government information kept within government . . . *reduces industry's ability to prepare and respond to concerns.*
- Industry threat and outage information shared only within industry . . . *leaves government interests under-protected and eliminates potential benefits of government assistance during a crisis.*
- Information sharing kept within a nation-state government . . . *weakens the ability of other governments to prepare and respond, and negatively impacts the reliability and security of all networks connected to those of the uninformed nation-states.*
- A mandated environment for information sharing not built on mutual trust . . . *results in sharing only to the extent of the mandate, potential unintended consequences, and lost opportunity to benefit from a common body of knowledge.*

Next Steps

Relative to the other Recommendations in The Report, this one takes a considerably longer time to develop to its full potential. This is because it is based on trust and the development of trust requires time – years. This is all the more reason for the initial steps to be taken without delay. Following are suggested next steps that can facilitate The Recommendation's implementation and the building of that precious trust.

4-1. The private sector and nation-state governments should investigate, and where appropriate, join some of the excellent information sharing organizations that already exist, learning their methods and creating an even larger pool of knowledge, mutually benefiting all organizations.

4-2. The private sector and nation-state governments should convene to establish a trusted environment for information exchanges centered around functional roles, such as, customer stakeholders, government regulators, equipment suppliers, and operators.[176] Existing fora should be used as appropriate. A gap analysis should be completed to help identify where other communities could be created. The following activities should support this step:

- Identify those areas in which cooperation is not effective through existing mechanisms and where the establishment of information sharing and best practice development could improve GUCCI resilience and reliability.

- Map identified gaps onto the categories that enable the appropriate expertise to be readily identified and engaged.[177]

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[176] Those most experienced with effective information sharing emphasize the importance of getting the architectural model that best aligns with the interests of the parties invited to participate. An additional architectural element is the flexibility to selectively share and unshared with members of a given community. A "star" or centralized arrangement is a topology where all sensitive information passes through an entity, which then shares with community members. An alternative is the mesh network, which encourages information sharing directly between parties willing to share. By enabling sharing to thrive where trust exists, the end result will be substantially more information being shared.

[177] The 8i framework can serve this purpose.

4-3. Participants should agree on a model to be implemented. In so doing, consideration should be given to the following insights:

- The scope and remit of the information exchange should be clearly defined.

- Trusted information sharing can only be achieved if the communities are small enough to allow personal trust to develop. Multiple trusted sharing communities will likely be needed.

- Participants must recognize that there are barriers to trusted information sharing and ensure the proposals address these to ensure they are pragmatic and achievable. Typical barriers include: lack of trust, competition law, lack of awareness, commercial pressures, and lack of an independent facilitator or trusted third party.

- Some types of information will be more sensitive than others and some will have more value than others. Many trusted information sharing communities start by sharing low value, less sensitive information and as trust develops the community can move up the value chain. This can sometimes take years to mature and therefore it is really important to identify existing communities who already have a certain level of trust.

4-4. Participants should begin to share information with peers, as appropriate.

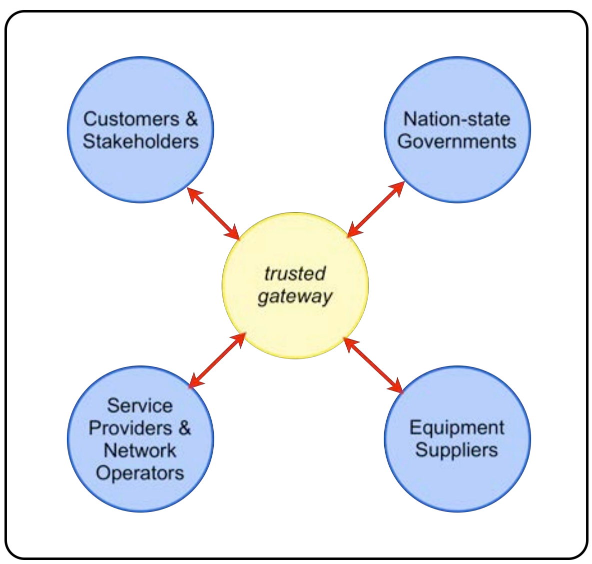

Figure 32. Nested Information Exchange Model[178]

[178] Harrison, John; Hill, G, Todd, M., *ROGUCCI White Paper on Best Practices and Trusted Information Sharing*, Landitd, U.K. 2010.

Measures of Success

The successful implementation of The Recommendation can be gauged by the following measures:

Scope clarified. The industry defines the Global Undersea Communications Cable Infrastructure.

Deep awareness. Nation-state governments are appropriately aware of sensitive information of importance to the security and prosperity of their nation-state and at regional, international and global levels.

Financial services sector. The industry engages special challenges and concerns of the international financial sector with the aim of improving the resilience schemes for systems supporting financial services.

Best Practices developed and shared. Industry experts share best practices for promoting the reliability, resilience and robustness of GUCCI. Information sharing is viewed as a means to an end. The process ultimately underpins a top-level analysis of the issues that currently undermine the resilience of the global information infrastructure.[179]

Smarter chain. The reliability of GUCCI is strengthened through enhanced stakeholder awareness, and the concomitant more complete contracted services and infrastructure investment.

[179] Achievement of this measure implies the establishment of effective international fora, as well as fora within nation-states (to include private sector) that will be able to benefit from the information flowing.

5.5 New International Governance

Purpose

The Recommendation addresses the issue of *how the undersea communications cable industry supports the needs of its stakeholders in providing the information they need to manage their dependence on it.*

Background

The Report establishes the need for dealing with individual undersea cable systems as an aggregate, i.e. global level. The need is based on the limited focus of commercial interests that manage individual systems, the difficulty stakeholders have in performing due diligence in managing their operational risk and the extremely high level of importance that this infrastructure plays in the world.[180]

The industry has historically recognized value in coming together for discussing various aspects of its operation. There are a number of existing organizations that represent and address some of the concerns of interested affinity groups involved in various aspects of the undersea cable infrastructure. [181] Reliability is within the scope of some undersea cable industry cooperative efforts. These fora have brought together equipment suppliers, network builders and operators and other special industry players such as surveyors and repair ship fleets. Some of them have facilitated joint studies and have provided guidance that is made available to the industry or public, as appropriate.[182] These include analyses of specific outages, trends in outage causes, best practices for addressing them, and advocacy for international policy agendas. Some groups are re-examining their charters to determine how they might address some of the new or more critical issues of the nature discussed at the ROGUCCI Summit.[183]

However, as stakeholders better comprehend the degree of their dependence on GUCCI, they require more from their interface with it. For example, stakeholder participants of the ROGUCCI Global Summit emphasized that the global view provided by the ROGUCCI process needs to continue to be championed. They identified a number of issues that would benefit from an ongoing process and efforts to systematically and comprehensively address several cross-industry and inter-government related problems at a global level. The increasing dependencies and criticality of this undersea infrastructure to a broad range of stakeholders further appeared to be evidence of interest and the need for some governance structure to better permit providers and stakeholders to address key issues in a comprehensive and strategic manner.[184] Financial sector stakeholders described this as the "system-wide" view.[185] Other observations from financial sector stakeholders were that the undersea communications industry would benefit from more inclusive participation in industry collaborative programs, more structured governance, better coordination and a unified voice. Specific mission areas for new governance would ideally include defining expectations for the industry, engaging representative stakeholders and articulating ASPR that would advance GUCCI resilience.[186]

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[180] See Introduction, Sections 2.1, to 2.3.

[181] These include the Atlantic Cable Repair and Maintenance Agreement www.acmaweb.ne), International Cable Protection Committee (www.iscpc.org), Submarine Cable Improvement Group (www.scig.net), Submarine Telecoms Forum (www.subtelforum.com), SubOptic (www.suboptic.org) and the Universal Jointing Consortium www.ujconsortium.com.

[182] Key Observation 66, Competitive Differentiation, Section 4.3.

[183] Key Observation 39, Not a Role Model *Yet,* Section 4.2.

[184] Summit participants suggested collaborative efforts to identify problems, develop alternative solutions and provide expert guidance and leadership. Also, such work would be of distinct benefit to decision makers, who are dealing with these complex issues, both from an educational and awareness perspective and a source of expert information.

[185] The financial services sector stakeholders established the fact that it has an international view that is complete in terms of capturing all the necessary elements that make up its system.

[186] Key Observations 71, Business Impact Disconnect, Section 4.3.

Recommendation 5
The private sector should establish a new international governance framework for global undersea communications cable infrastructure to provide optimum support for its resilience through cross-sector coordination and effectively support stakeholder interests.

Required Commitment

To sustain the viability of The Recommendation, the private sector and stakeholders must be committed to defined courses. Specifically,

- ☐ Stakeholders must maintain a proactive posture in engaging this critical international infrastructure partner.
- ☐ Existing industry fora must evaluate their charters, membership and commitments, in light of the stakeholder and internal industry needs.
- ☐ Existing industry fora must, as appropriate, be either willing to make charter and membership representation adjustments, or be supportive of sister organizations playing new complimentary roles.
- ☐ Private sector companies must provide expert and leadership resources to champion new governance functions.

Benefits of New International Governance

Stakeholders will have the opportunity to bring their concerns to the industry in a more organized fashion, and encourage the availability of information regarding benchmark performance levels for GUCCI, supporting the objectives of Recommendation 7. Industry members will have improved effectiveness in cooperation, and have a unified voice when appropriate. Existing industry fora can be more effective at fulfilling their current missions by channeling out-of-scope issues (outside of their mission or realm of influence) to complimentary partners. The industry will attain an augmented capability to respond with flexibility and speed on issues that may arise, like those identified in The Report.

Alternative Approaches and Their Consequences

Alternatives to this approach include the following:

- Defer to government sector for oversight of industry cooperation . . . *dulling the value of the industry's expertise, introducing delays in actions, and inviting unwanted regulation.*
- Existing fora remain on current course and no new governance is established . . . *accepting suboptimum industry coordination and proactive engagement with stakeholders.*

Next Steps

Suggested next steps to generate momentum toward the implementation of The Recommendation include:

5-1. Existing industry fora should re-evaluate their charters and membership and make adjustments, as appropriate.

5-2. New governance structure should be established, complimenting the existing effective functions.

5-3. Participation is expanded to be sector-wide.

5-4. Representative stakeholders are invited to be part of the new governance structure.

Measures of Success

The successful implementation of The Recommendation can be gauged by the following measures:

New governance structure. New governance structure and process are established that provide effective sector-wide coordination and addresses interests of stakeholders, fostering and facilitating the coordination of cross-sector activities and initiatives designed to improve the resiliency of the undersea cable infrastructure and services at a global level.

Finance sector participation. The finance sector is actively engaged as a stakeholder representative in the new structure.

Unified voice. The undersea communications cable industry has a process for discussing issues, developing consensus and representing itself with a unified voice at a global level.

5.6 International Communications Infrastructure Standard for the Financial Sector

Purpose

The Recommendation addresses the issue of how the financial sector should manage its dependence of GUCCI specifically in the context of an overall improved management program for its dependence on information and communications technology in general. While one sector is the focus in The Recommendation, it should be viewed as a representative of all international critical sectors.

Background

The world's international undersea communications cable infrastructure continues to operate at highly reliable levels and continues to provide tremendous service to the financial services sector. Indeed, the reliability of financial sector operations owes much to its ability to place extremely high confidence in its communications service providers and their networks.

The financial services sector continues to evolve globally with increasing dependence on international communications every step of the way.[187] The sector is achieving much by reducing market risk through such mechanisms as automation and compressed settlement intervals. On the other hand, it is raising its operational risks in the process, by such things as increased dependency on GUCCI.[188] [189] The Bank of International Settlements, Basel Committee on Banking Supervision has elevated operational risk as a critical component of its supervisory framework.[190] As with anything new, managing operational risk has not yet been fully mastered. Indeed re-thinking is needed around business processes, resiliency planning and continuity of operations.[191] Ideally, the information could be limited to focusing on expected downtime for international connectivity.[192] However, depending on the thoroughness behind such analyses, additional information may be needed, such as geographic route information for purchased circuits and bandwidth, and equipment and service supplier information that can contribute to common failure modes.[193] [194] The financial sector would benefit much from the systematic and comprehensive perspective offered by an intrinsic vulnerability approach utilizing the Eight Ingredient (8i) Framework.

Recommendations 4 and 7 position the communications industry to better share information and provide needed information to the financial sector, respectively. Correspondingly, this Recommendation calls on the financial services sector to better define its needs and expectations, and to develop a structure to organize operational risk guidance that allows users to manage their growing global dependency on GUCCI.[195] The need to manage international communications services as a priority is not new to the financial sector. Recent activities include the development of the U.S. Financial Service Sector Coordinating Council *Resilient International Telecommunications Guidelines for the Financial Service Sector*, which underscored the imperative for improved management of the operational risk in resiliency planning.[196] [197]

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[187] Key Observation 9, Bank on It, Section 4.1.
[188] Key Observation 10, "Snap to a Halt!", Section 4.1.
[189] Key Observation 11, Financial Sector Sensitivity, Section 4.1.
[190] Bank of International Settlement, www.bis.org .
[191] Key Observation 15, Emerging Role of Operational Risk, Section 4.1.
[192] Key Observation 38, Statistical Analysis, Section 4.2.
[193] Key Observation 13, You Get What You Pay For – Maybe, Section 4.1.
[194] Key Observation 12, The Technologically Blind, Section 4.1.
[195] Key Observation 16, Financial Sector Due Diligence, Section 4.1.
[196] Pacine, Wayne and Callahan, Roger, www.fsscc.org, FSSCC, 2009. Included in the document are: a description of the undersea cable infrastructure and commonly used configurations, a description of general risks to the undersea cable infrastructure, suggestions for analyzing requirements and risks, a description of practices that need to be considered for basic

> As the global economy continues to expand, reliable connectivity and highly resilient international telecommunications systems are essential. Revenue-generating and revenue-supporting financial services operations translate to a need for near 100 percent global network availability coupled with application-friendly round-trip latency, low jitter, and near-zero packet loss. Thus, for any global application deployment, end-to-end cable path resiliency becomes an important aspect of the initial planning, procurement, and provisioning process and must be considered when engaging any global carriers and service providers. [198]

However, such progress stops short of calling for international cooperation around a core standard and for its voluntary utilization, which will enable the more precise management of resilience and operational risk on a global basis.[199] A standard should appropriately incorporate the financial services sector sensitivity to latency.[200] [201] Therefore, The Recommendation builds on the progress achieved to date and defines a course that will do much to close the gap between common practices and optimum due diligence.

Recommendation 6
The international financial sector should introduce a new core standard for its information and communications technology dependence that will include guidance on assuring institutional resilience and managing the operational risk associated with undersea communications cable infrastructure.

Required Commitment

To sustain the viability of The Recommendation, the private sector must be committed to defined courses. Specifically,

- The international financial sector must recognize GUCCI reliability as a strategic priority for the stability of its operations.
- The international financial institutions must commit operational risk managers to developing the details of global guidelines.[202]
- The financial sector and international communications industry must commit to a partnership to develop a core standard that both can agree on.
- The financial sector members must voluntarily implement the developed core standard.
- The world's international financial authorities must utilize these standards in their determination of ratings and other stability-related decisions.[203]

types of service, suggestions for engaging service providers as partners in a trusted relationship at the beginning and throughout the life cycle of operations, a discussion of contract considerations and important aspects of managing the ongoing relationship with international telecommunications service providers.

[197] Key Observation 14, Two Modes of Awareness, Section 4.1.
[198] Ibid. pages 18, 20.
[199] Key Observation 12, The Technologically Blind, Section 4.1.
[200] Key Observation 21, Rare Glimpse of c's Limit, Section 4.2.
[201] Key Observation 23, Alternatives Are Not Up in the Air, Section 4.2.
[202] central banks, markets, institutions, bank supervisors, investment firms, etc.
[203] i.e. Individual financial sector regulators and the Financial Sector Assessment Program (FSAP) of the IMF and World Bank.

Benefits of an International Communications Infrastructure Standard for the Financial Sector

The implementation of The Recommendation will bring key benefits to the international financial sector, other stakeholders and the international communications industry. An international benchmark for due diligence in managing GUCCI will be established. In addition, the sector will more fully understand the risks associated with its current and evolving dependencies in this vital area. Also, other sectors will benefit by the financial sector's championing role, which simultaneously represents the vital interests of many other stakeholders. Finally, the development of a global standard will strengthen the necessary partnerships with the communications industry that are imperative for ensuring appropriate long-term technology evolution that will accompany the world's growing dependence on this infrastructure.

Alternative Approaches and Their Consequences

Alternatives to this approach include the following:

- Assimilate default standards and practices . . . *mission critical interests will be under-represented*
- Develop multiple standards . . . *the financial sector will manage its operational risk inconsistently, and the clarity of its interface with the undersea communications industry will suffer.*[204]
- Continue status quo of attention . . . *the financial sector will be unable to manage its operational risk effectively.*[205]

Next Steps

Suggested next steps to generate momentum toward the implementation of The Recommendation include:

6-1. A neutral party that is a well recognized international organization should convene operational risk managers from the international financial sector, along with other critical stakeholders and international undersea communications cable experts to define a process for developing a global standard for operational risk management in this area.[206] The core standard development initiative should utilize the 8i framework to ensure coverage of the full scope of what needs to be considered.[207] [208] [209]

6-2. The financial sector and communications industry should implement this process to jointly produce a new global core standard for international communications infrastructure resilience assurance.

6-3. The world's senior economic leaders should promote voluntary adoption of the core standard, and should utilize nation-state institutional implementation as decision support for its policy and practices, as appropriate.[210]

[204] i.e. the critical international user communities will manage their operational risk inconsistently, and the lack of consistency will not provide clarity to potentially valuable investments by the undersea communications industry and users.
[205] i.e. the critical users will manage their operational risk based on limited knowledge and information with the likely potential that unknown risks impact their operations, and the opportunity for more clarity for potential investments will be missed.
[206] Key Observation 71, Business Impact Disconnect, Section 4.3.
[207] Use of the 8i Framework recommended by Dr. Nasser Saidi, DIFC Chief Economist, in his keynote address to the ROGUCCI Global Summit, October 2009.
[208] Section 3.
[209] Key Observation 51, Intrinsic Vulnerability Approach, Section 4.2.
[210] e.g., the G8, G20, World Bank, IMF.

Measures of Success

The successful implementation of The Recommendation can be gauged by the following measures:

Global Core standard. A core standard for international communications reliability is established for the international financial sector. This standard is recognized with the similar stature of existing core standards for the international financial sector (Appendix D).[211] [212]

Voluntary implementation. Financial sector institutions, firms, markets and others voluntarily implement the core standard to enhance the reliability of their international connectivity.

Decision support. The core standard is used to guide private sector investment, international supervisory bodies and nation-state priorities.

[211] e.g., the twelve core standards for Sound Financial Systems of the Financial Stability Board (Appendix X).
[212] More specifically, the standard is recognized by the international financial sector supervisory bodies as best practices for those that provide important international systemic functions that would affect global or significant institutional financial stability; and by other critical global user communities and international service providers.

5.7 Measurements for Stakeholder Due Diligence

Purpose

The Recommendation addresses the issue of *how the undersea communications cable industry supports the needs of its stakeholders by providing the information they need to manage their dependence on it.*

Background

Throughout the world, many stakeholders are depending on the reliability of GUCCI. But the dependence of some stakeholders stands out for its extremely high import. One such stakeholder is the financial sector.[213] In similarity to vital dependence of the transportation sector on fuel, and agriculture on rain, the modern financial sector cannot operate without GUCCI.

As the financial services sector continues to evolve on a global basis, increased reliance on information and communications technology (ICT) translates directly into increased reliance on undersea cable infrastructure. Traditionally, the focus of resilient communications has been within a continent, specifically, the "last mile" from the institution to the first node of a robust terrestrial network. Today's global markets are vitally dependent on resilient international connectivity. Major gains achieved in reducing market risk through such mechanisms as automation and compressed settlement intervals are offset by increased operational risks through increased dependencies on ICT in general, and undersea cable infrastructure, specifically.[214]

Those responsible for overseeing their institution's exposure to operational risk cannot perform due diligence because there is insufficient information available.[215] The fundamental information that is needed centers around a statistically based expectation of downtime for international connectivity.[216]

There is basic lack of published, or otherwise available, information on GUCCI reliability for stakeholders that play critical roles in societies around the world.[217] This in turn prevents advanced analysis of outages and trend information and the formulation of a coordinated response to resilience issues.

> The time is right for a multi-national, cross-industry forum comprised of the undersea cable infrastructure community, major enterprise customers, ISPs, and data hosting centers that monitor their global infrastructure to develop models for global infrastructure resiliency.[218]

The implementation of Recommendations 4 and 5, *Best Practices and Trusted Information Sharing*, and *New International Governance*, respectively, will create structure and spirit to enable this Recommendation to succeed.[219] Further, Recommendation 6, *International Communications Infrastructure Standard for the Financial Sector* will be enabled by the implementation of this Recommendation.

[213] Key Observation 9, Bank on It, Section 4.1.
[214] Key Observation 10, "Snap to a Halt!", Section 4.1.
[215] Key Observation 16, Financial Sector Due Diligence, Section 4.1.
[216] Key Observation 38, Statistical Analysis, Section 4.2.
[217] Key Observation 17, Waiting, Section 4.1.
[218] Makris, Spilios and Lordi, Nick, *Undersea Cable System Outages and Global Infrastructure Resilience: A Discussion of Issues in Managing Third-Party Expectations*, Proceedings of the IEEE CQR International Workshop, 2009.
[219] Key Observation 66, Competitive Differentiation, Section 4.3.

Recommendation 7
The private sector should establish a method of providing basic reliability performance statistics to stakeholders.

Required Commitment

To sustain the viability of The Recommendation, the private sector and stakeholders must be committed to defined courses. Specifically,

- Stakeholders must maintain a proactive posture in engaging critical international infrastructure partners.
- Private sector companies must be willing to share the outage information needed to support overall GUCCI performance measurements, with appropriate non-disclosure agreement protections.
- Existing industry fora must evaluate their charters, membership and commitments, in light of the stakeholder and internal industry needs.
- Existing industry fora must, as appropriate, be either willing to make charter and membership representation adjustments, or be supportive of sister organizations playing new complimentary roles.
- Private sector companies must provide expert and leadership resources to champion new governance functions.

Benefits of New International Governance

Stakeholders will have sufficient - and sufficiently clear - information regarding benchmark performance levels for GUCCI, enabling them to perform due diligence in managing their operational risk. Industry members will have improved effectiveness in cooperation, and have a unified voice when appropriate. Existing industry fora can be more effective at fulfilling their current missions by channeling out-of-scope issues (outside of their mission or realm of influence) to complimentary partners.

Alternative Approaches and Their Consequences

Alternatives to this approach include the following:

- Governments or stakeholders force the industry to report outages . . . *resulting in unwanted regulation and cost, inefficient use of expert resources as they are needed to support compliance fulfillment, and increased defensive posturing by the industry.*
- Outage analysis continues at the current limited practice . . . *accepting suboptimum industry coordination and limiting stakeholders' ability to manage risks.*

Next Steps

Next steps to generate momentum toward the implementation of The Recommendation are suggested below. **This process should hold strict standards for the protection of commercial interests by ensuring that no competitive disadvantage results from any part of it.**[220]

7-1. The undersea communications industry should establish a trusted environment in which to submit outage and other critical infrastructure reliability data. [221]

7-2. The collected information should be aggregated at an industry level, where subject matter experts from across the industry conduct joint analyses to determine statistically significant trends based on historical events, and systematically assess intrinsic vulnerabilities that may pose latent reliability challenges.[222]

7-3. The industry should provide a report on the "Health of Global Undersea Communications Cable Infrastructure" to support its stakeholders. The Report should provide stakeholders with the essential information that stakeholders need to perform risk management.[223]

7-4. Continuous improvement should be made for the steps above, increasing industry participation, "peeling the onion" to study the next layer of problems, and confirming with stakeholders that their need for basic information is being met.

Measures of Success

The successful implementation of The Recommendation can be gauged by the following measures:

Outage database. The industry sets up a database to collect outage information, ensuring that no competitive disadvantage is gained from the process.

Joint analysis. Subject matter experts are lending expertise in collaborative efforts to understand reliability influencers and suggest countermeasures.

Unified voice. The undersea communications cable industry produces an authoritative description of its performance at a global level, satisfying stakeholder needs.

[220] The existing trusted environment models referenced throughout the Report can be used to build confidence in the viability of this approach.
[221] Recommendation 4, *Best Practices and Trust Information Sharing*.
[222] Section 3 provides a reference for these systematic intrinsic vulnerability analyses using the 8i framework.
[223] Recommendation 6, *International Communications Infrastructure Standard for the Financial Sector*.

5.8 Improved Cable Protection Agreements, Standards, Policies and Regulations

Purpose

The Recommendation addresses the issue of *how to provide better protection of deployed cable systems using available or new policy instruments.*

Background

The protection of undersea cables in international law is well established dating back to the 1880s.[224] Cable protection laws have been updated with new policy at the international level.[225] However, too often there is not corresponding nation-state-level policy to match the priority established at the international level. As a result, avoidable cable damage is routinely experienced.

Undersea communications cables are especially vulnerable in the transition from deep water to their landing site.[226] This is due to the shallow water and increased activity in these areas.[227] It is therefore imperative that these cables be supported with special protection in these particular areas.

Nation-states for the most part understand the importance of GUCCI to their economy and security.[228] Much of the world's most robust economic growth is taking place in regions where there is traditionally less attention paid to critical infrastructure protection, though this is not a problem confined to emerging market regions.[229] Some countries are moving forward with an approach to define special areas for undersea communications cable passage.[230]

Since the cable infrastructure may cross many borders, government guarantees that support infrastructure reliability are needed. Ideally, these provisions would include policies ensuring that providers will have timely access to restore a failed part of a system.[231] [232]

Recommendation 8
Nation-state governments should implement best practices for protecting undersea communications cables within their sovereign waters.

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[224] Key Observation 89, A History of Importance, Section 4.4.
[225] Key Observation 82, UNCLOS, Section 4.4.
[226] Key Observation 53, Landing Sites, Section 4.2.
[227] Key Observation 60, Swelling Marine Activity, Section 4.2.
[228] Key Observation 19, Nation-State Stakeholders, Section 4.1.
[229] Key Observation 6, Traffic Growth Is Part of Development, Section 4.1.
[230] Key Observation 96, Controlled Approaches, Section 4.4.
[231] *Resilient International Telecommunications Guidelines for the Financial Service Sector,* Pacine, Wayne and Callahan, Roger, Financial Service Sector Coordinating Council www.fsscc.org, 2009.
[232] Key Observation, 90, It Needs Some Teeth, Section 4.4.

Required Commitment

To sustain the viability of The Recommendation, nation-state governments and the private sector must be committed to defined courses. Specifically,

- ☐ Nation-state governments must make the protection of undersea communications cable infrastructure a priority.
- ☐ The private sector must assist the government in understanding the types of damage experienced.
- ☐ Governments must be able to improve their protection through effective policies and practices.[233]

Benefits of Improved Cable Protection ASPR

Benefits of the implementation of The Recommendation will include improved reliability due to better cable protection and due to shorter time intervals when dealing with approvals for maintenance.

Alternative Approach and Consequences

Alternatives to this approach include the following:

- o Do nothing, waiting for an event to occur and then reacting . . . *forfeiting advantages that could have been achieved with efficient government policy and practice.*

Next Steps

Suggested next steps to generate momentum toward the implementation of The Recommendation include:

8-1. Nation-states and cable system operators should convene for the purpose of identifying best practices among the represented governments. The private sector should articulate its needs and explain the impacts when these needs are not met.

8-2. Agreement should be sought around the articulation of the best practices shared.

8-3. The best practices should be implemented by the governments participating in the process, then also shared with governments not participating in the process.

Measures of Success

The successful implementation of The Recommendation can be gauged by the following measures:

Prioritized mission: Government agencies are aligned on the priority, policies and practices for protecting undersea communications cable infrastructure.

Best practices: Governments have best practices guidelines to reference.

Practice speed. The government conducts its business in an efficient manner.

[233] Key Observation 100, Eating Dust, Section 4.4.

5.9 Government Inter-Agency Coordination for Undersea Cable Infrastructure

Purpose

The Recommendation addresses the issue of *how to transform the governments' lack of inter-agency coordination when it comes to policy for undersea cable protection.*

Background

Effective and efficient government agency coordination is a challenge that has been around since governments were first established. There are a number of challenges to overcome, including different responsibilities, different – and sometimes conflicting – priorities and varying types of available resources.

While the inter-governmental coordination is also an area for concern, this Recommendation focuses on the coordination within a single nation-state. The undersea cable industry is too often impacted by government policies that impede its efforts to improve the reliability of its systems and services.[234] One of the primary causes of this is poor coordination among government agencies.[235] It is understandable that each organization will have its own primary interests, however, this often results in inconsistent policy, confusion and delays.

There are no easy solutions. Drawing attention to this problem is a first step, but it must be followed with commitments and actions for improvements to be realized. Some of the opportunities for progress may lie in greater education and awareness among key policy makers and regulators, the quantification of the negative impact of uncoordinated government and the private sector's capture of the best practices for this area, and public recognition of role model behavior.

The undersea cable industry's frustration with the lack of intra-governmental coordination has in the past been an accepted annoyance. However, as the importance of this international infrastructure becomes more apparent, this avoidable barrier to reliability is increasingly unacceptable to the private sector as it strives to improve the reliability of undersea communications cable systems.

Recommendation 9
Nation-state governments and the private sector should establish a best practice model for undersea communications cable inter-agency coordination to ensure consistent policies and practices.

[234] Key Observation 97, Good Housekeeping?, Section 4.4.
[235] Key Observation 79, Paperwork, Section 4.3.

Required Commitment
To sustain the viability of The Recommendation, nation-state governments and the private sector must be committed to defined courses. Specifically,

- Nation-state governments must make its oversight of undersea communications cable infrastructure a priority.
- The private sector must assist the government in understanding its observed inconsistencies and impact, and provide role model references.
- Governments must be able to improve their inter-agency coordination to provide consistent policy and speedy implementation.

Benefits of Improved Cable Protection ASPR
Benefits of the implementation of The Recommendation will include improved reliability due to better cable protection and shorter time intervals when dealing with approvals for maintenance.

Alternative Approach and Consequences
Alternatives to this approach include the following:

- Maintain status quo . . . *GUCCI remains sub optimally managed as a critical nation-state asset.*

Next Steps
Suggested next steps to generate momentum toward the implementation of The Recommendation include:

9-1. Nation-states and cable system operators should convene for the purpose of identifying best practices among the represented governments. The private sector should articulate its needs and explain the impacts when these needs are not met.[236]

9-2. Participants should seek agreements around the articulation of the best practices shared.

9-3. The best practices should be implemented, shared with governments not participating in the process.

Measures of Success
The successful implementation of The Recommendation can be gauged by the following measures:

Inter-agency coordination: Government agencies are aligned on the priority, policies and practices for supporting undersea communications cable infrastructure. [237]

Policy clarity. The government and the private sector understand what the policies that affect undersea communications cable industry are.

Authority exercised. Nation-states exercise their authority to ensure policies that will promote undersea communications cable resilience.

Practice speed. The government conducts its business in an efficient manner.

[236] Quantification of the affects of lack of government coordination may be a useful vehicle for conveying the importance of this issue.
[237] It is understandable that some practices may not be suitable for every situation.

5.10 Education and Awareness of GUCCI Critical Role

Purpose
The Recommendation addresses the issue of *how to address the profound gap between critical dependence and awareness that stakeholders and the general public have regarding GUCCI.*

Background
The world's undersea communications cable infrastructure continues to operate at highly reliable levels and continues to provide tremendous service to the daily operation and long-term growth of both established and emerging economies in all parts of the world. GUCCI is an essential part of the modern world.

However, there is a profound <u>un</u>awareness on the part of the general public, business enterprises, critical sector stakeholders and government regarding their dependence on undersea communications cable infrastructure.[238] [239] While the increasing rate of dependence climbs steeply, there is no corresponding movement in consciousness of the dependence or the risks associated with it.[240] It being imperfect, like any other critical infrastructure, due consideration needs to be given to its priority in decisions affecting it, ramifications of its failure and opportunities to promote its resilience.

There are times when the public is temporarily conscious of the importance of these cables.[241] This is during times when there are cable cuts that affect Internet service. Major or multiple cuts in one part of the world can affect all parts of the world. The initial impact is typically during the first hours, until manual re-routing can be engineered. Then the impaired throughput (slow Internet speed) is experienced for days or weeks, depending on the event. In fact at least four incidents have had this effect in recent years.[242]

Those most 'in-the-know' about how important this infrastructure is can be in a very difficult position.[243] The traditional approach of 'security through obscurity' has been soundly outdated with the emergence of the Internet. Broad and detailed information such as cable technologies, equipment manufacturers, cable routes, repair ships, landing station sites, and more, are available for anyone with Internet access.[244] What has traditionally been a nation-state security issue has spilled far over into the laps of a much broader community of stakeholders.[245] [246] [247] The circumstances are compelling.[248] New approaches are needed

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[238] Key Observation 1, Public Unaware, Section 4.1.
[239] Key Observation 14, Two Modes of Awareness, Section 4.1.
[240] Key Observations 5, User Expectations Are High, Section 4.1.
[241] Some events even have unique Wikipedia entries for them, e.g., "2008 Submarine Cable Disruption."
[242] In order from most recent: August 2009 Typhoon Morakot, December – multiple cuts, 2008 Mediterranean Sea, January–February Middle East, December 2006 Hengchun Earthquake, . . . each of these involved multiple simultaneous cable cuts.
[243] Key Observation 98, Batten Down the Hatches, Section 4.4.
[244] Key Observation 48, Information Smorgasbord, Section 4.2.
[245] Key Observation 19, Nation-State Stakeholders, Section 4.1.
[246] Key Observation 88, <u>Inter</u>national Infrastructure, Section 4.4.
[247] The author's father worked on submarine cable system repeater systems at Bell Labs during the 1960s. The ability for these repeater systems to identify the location of a cable cut from an adversary during the Cold War was of significant national security interests.
[248] Key Observation 22, 99+%, Section 4.2.

that properly educate stakeholders to enlist them as allies, and that are also keen to protect their and nation-state security interests.

Recommendation 10
The undersea communications cable industry should begin an outreach campaign that provides appropriate education to government and other stakeholders regarding GUCCI function in the stability of their operations.

Required Commitment

To sustain the viability of The Recommendation, the private sector and stakeholders must be committed to defined courses. Specifically,

- ☐ The undersea communications cable industry must recognize the unacceptable nature of the existing dependence-unawareness gap.
- ☐ The undersea communications cable industry must commit to action to resolve the under-education of those dependent on it.
- ☐ Stakeholders must be diligent in achieving appropriate levels of knowledge regarding their dependence and developing management best practices regarding their dependence on GUCCI.

Benefits of Education and Awareness of CUCCI Critical Role

Stakeholders will have the necessary awareness of their vital dependence on GUCCI. The needed context will be provided for proper decision support for many waxing ASPR needs, such as improved cable protection, regional negotiation and investment in physically diverse cable routes, emergency preparedness for hostile maritime crises, and need of a back up plan for catastrophic loss of GUCCI.

Alternative Approaches and Their Consequences

Alternatives to this approach include the following:

- o Incomplete or otherwise ineffective education campaign . . . *will provide a different, inappropriate perception.*
- o Security through obscurity . . . *will fail as extensive information is already in the public domain and potential adversaries to GUCCI stability tend to be highly technical.*[249] [250] [251]

[249] Appendix B.
[250] Gambetta, Diego, and Hertog, Steffen, *Engineers of Jihad*, Sociology Working Papers, Paper Number 2007-10, University of Oxford, 2007.
[251] Key Observation 100, Eating Dust, Section 4.4.

Next Steps

Suggested next steps to generate momentum toward the implementation of The Recommendation include:

10-1. The private sector should assess the education gap and develop a countermeasure strategy, which includes the main messages.

10-2. Existing industry fora should agree on what role each can play in implementing the strategy.

10-3. Stakeholders should develop a metric to measure progress in achieving critical awareness objectives.

10-4. The private sector should work together to update the educational strategy, program and messages, as appropriate.

Measures of Success

The successful implementation of The Recommendation can be gauged by the following measures:

Education strategy. The private sector develops an educational outreach program.

Stakeholder commitment. The stakeholder community establishes objectives for achieving awareness of dependence and identifies best practices for managing its dependence.

Gap removed. The dependence-unawareness gap regarding dependence on undersea communications cable infrastructure is removed.[252]

[252] Key Observation 1, Public Unaware, Section 4.1.

5.11 Mechanisms for Handling Overload Demand

Purpose

The Recommendation addresses the issue of *how to prepare for traffic overload scenarios for the global undersea communications cable infrastructure*.

Background

The current situation is one in which there is considerable "unlit" spare capacity on fibers within the GUCCI.[253] In addition, technological advances have enabled deployed systems to be used to deliver much greater bandwidth than they were originally designed, and ongoing research promises continued advances in this area.[254] [255] [256] [257] There is no immediate alarm regarding existing capacity availability.

However, there are several reasons for increased vigilance regarding future infrastructure congestion.[258] First, an ever-present, intrinsic vulnerability of any communications system, network or infrastructure is its finite capacity limitation for payload throughput. Second, the world is currently experiencing an explosive rate of increasing demand for bandwidth, consuming spare capacity at an aggressive pace.[259] Third, the nature of the traffic is very different today. What used to be primarily voice or message content of fixed size, is more and more becoming image and video content of nondeterministic (but very large) size. Fourth, with the viral phenomenon of some new applications and global connectivity, there is no guarantee that the rise in user demand based on these types of services will allow the spare capacity buffer levels we are used to.[260] For example, a major disaster or other scenario may trigger end user activity (e.g., sharing videos) that presents an aggregate payload above maximum capacity limits over an extended period of time. Fifth, a cyber attack could unleash volumes of traffic or affect network control channels, resulting in overload conditions. Finally, a loss of satellite or a significant portion of terrestrial infrastructure could place significant expectations on GUCCI. In light of these factors, an overload condition is a very real scenario, which may present itself intermittently in unexpected fashion, or as a temporary situation due to a specific event.

Terrestrial networks have anticipated the need for managing overloads with the deployment of various mechanisms. Prioritization schemes are one such mechanism.[261] The International Telecommunications Union - Telecommunications Standardization Sector (ITU-T) supports an international standard with a five-tiered prioritization scheme.[262] These mechanisms enable governments to authorize users for priority treatment. While initially developed for basic voice calls, they currently extend to data and video applications. Service providers can provide another type of prioritization in the form of a service level agreement (SLA), whereby an end-user subscribes to a special premium service that ensures a specified

[253] Key Observation 76, Spare Capacity, Section 4.3.
[254] Key Observation 27, DWDM, Section 4.2.
[255] Key Observation 28, Protocol Soup, Section 4.2.
[256] Key Observation 31, Heavy Light Technology, Section 4.2.
[257] Key Observation 40, Heroic Technology Breakthroughs, Section 4.2.
[258] Key Observation 65, Nothing But Time, 4.3.
[259] Key Observation 4, Bandwidth Thirst Management, Section 4.1.
[260] Key Observation 7, Everybody Wants It, Section 4.1.
[261] Government Emergency Telecommunications Service (GETS) is deployed in the U.S. to provide government-authorized users priority treatment between access points; whereas Wireless Priority Service (WPS) provides similar treatment over the air loop between a mobile subscriber and the cell tower.
[262] Emergency Telecommunications Service (ETS) and International Emergency Preference Scheme (IEPS).

level of performance. Both of these are examples of how limited capacity is allocated along predetermined arrangements.

In summary, GUCCI has limited capacity and it is conceivable that, like its terrestrial cousin, it may be impaired by overload conditions. How should limited capacity be managed? How can international coordination ensure that the communications most critical for continued government operation and security be maintained?

Recommendation 11
Network operators, service providers and stakeholders should develop and implement agreed upon mechanisms for handling traffic overload conditions for undersea communications cable infrastructure.

Required Commitment

To sustain the viability of The Recommendation, nation-state governments and the private sector must be committed to defined courses. Specifically,

- Nation-state governments must agree that some communications are more important than others and therefore require preferential treatment during times of infrastructure congestion.
- Nation-state governments must agree with each other on mutual preferential treatment of so designated traffic.
- Nation-state governments must provide incentives for private sector development and deployment of priority schemes.
- Nation-state governments, stakeholders, network operators and service providers must securely manage the administration of authorized priority traffic.
- Service providers and network operators must implement agreed-upon overload management mechanisms.

Benefits of Mechanisms for Handling Overload

When implemented, The Recommendation will provide a mechanism to ensure that the most important traffic is carried over undersea communications cable infrastructure that is congested.

Alternatives Approaches and Their Consequences

Alternatives to this approach include the following:

- Rely upon ability to maintain a sufficient buffer of spare capacity . . . *will result in indiscriminate blocking of traffic when overload conditions occur, as the statistical variability is ever more difficult to engineer for.*
- Discourage use and dependence on global connectivity . . . *would be cause for profound disadvantage to a nation-state in terms of technological and economic development.*
- Maintain the current course . . . *requires accepting indiscriminate loss of traffic when overload conditions are presented, acknowledging loss of critical communications.*

Next Steps

Suggested next steps to generate momentum toward the implementation of The Recommendation include:

11-1. The international financial community should determine the sufficiency of existing congestion management options, including SLAs, in order to determine whether due diligence for operational risk can be achieved, or new mechanisms are needed.

11-2. Nation-state governments should establish international agreements around GUCCI congestion management policies and practices.

11-3. Governments should provide appropriate incentives for the development and deployment of agreed upon mechanisms to manage overload conditions in GUCCI.

11-4. Standards development organizations (SDOs) should include GUCCI considerations in their ongoing deliberations.

Measures of Success

The successful implementation of The Recommendation can be gauged by the following measures:

Overload Strategy: Stakeholders have an established strategy for effectively handling GUCCI congestion scenarios.

International Cooperation: Nation-state governments establish agreements on the coordination of priorities when overload conditions are present in GUCCI.

Priority Communications: GUCCI is robust in ensuring that the most important communications are carried during the stresses of congestion.

5.12 Recognize GUCCI Catastrophic Loss As a Grand Challenge

Purpose

The Recommendation addresses the concern of *preparing for a large-scale loss of the world's undersea communications cable infrastructure*, by directing stakeholders to prepare for the worst case scenario and by calling on the scientific and engineering community to respond to a new grand challenge problem.[263]

Background

Nearly 100% of the world's inter-continental electronic communications traffic is carried by the undersea cable infrastructure.[264] [265] There is no back-up capability should it be lost.[266] Satellite capacity, if not carrying its existing traffic, would have carrying capacity two orders of magnitude too small.[267] [268] Terrestrial based routes would leave continents in isolation.[269]

The probability of such a failure is very low, however, **it is not zero**.[270] [271] The impact of such a failure on international security and economic stability could be devastating. The pace at which technology has been adopted and then depended upon is unprecedented in history. It is unclear if civilization can recover to its previous condition from the failure of a technology that has been so rapidly adopted without a back-up plan.[272] Without GUCCI, the world's economic financial market would immediately freeze.[273] But what would happen next? What are the options? What can be done to best prepare for this unlikely, but possible event?

Recommendation 12
Subject Matter Experts and Stakeholders should prepare for the worst-case scenario of a catastrophic loss of global undersea communications infrastructure by identifying best available alternatives and operational procedures. Preparation should include scientific and engineering research for long-term solutions.

[263] A grand challenge is a fundamental problem in science or engineering, with broad applications. The fundamental physical sciences, engineering, and mathematical underpinnings are similar for many of these problems. Examples of grand challenges are: more efficient automobiles and airplanes, improved environmental modeling, understanding the structure of biological molecules. *A Research and Development Strategy for High Performance Computing,* Executive Office of the President, Office of Science and Technology Policy, November 20, 1987.
[264] Key Observation 3, Heads in the Clouds, Section 4.1.
[265] Key Observation 22, 99+%, Section 4.2.
[266] Key Observation 58, No "Plan B", Section 4.2.
[267] Key Observation 23, Alternatives Are Not Up in the Air, Section 4.2.
[268] Key Observation 24, Payload Volume, Section 4.2.
[269] Australia; North America from Europe and Asia, etc.
[270] Key Observation 50, Looking Backwards, Section 4.2.
[271] Key Observation 51, Intrinsic Vulnerability Approach, Section 4.2.
[272] Kissinger, Henry, *Does America Need a Foreign Policy?* Toward a Diplomacy for the 21st Century, September 2002.
[273] Key Observation 10, "Snap to a Halt!", Section 4.1.

Required Commitment

To sustain the viability of The Recommendation, governments and the private sector must be committed to defined courses. Specifically,

- ☐ Governments and other stakeholders must encourage academic and private sector research to ensure appropriate resources are focused on this global challenge.
- ☐ Scientists and engineers must be devoted to developing alternatives.
- ☐ Stakeholders must conduct planning scenarios that consider true worst-case scenarios.
- ☐ The financial services sector must play a lead role in establishing the importance of this concern.

Benefits of a Recognizing GUCCI Catastrophic Loss As a Grand Challenge

When followed, The Recommendation will provide a benchmark understanding of the impact of catastrophic GUCCI failure and guidance on best alternatives and procedures in such a situation. It should spark new long-term research for alternatives to the current dependence. In addition, critical stakeholders will be more informed of the very low probability - yet possible – risk of GUCCI failure. Consequently, stakeholders can be prepared for the worst-case scenario.

Alternatives Approaches and Their Consequences

Alternatives to this approach include the following:

- Minimize public awareness of the issue by limiting research and discussion of issue to closed forums . . . *resulting in a less rigorous effort and limited stakeholder planning.*
- Discourage use and dependence on global connectivity . . . *would be cause for profound disadvantage to a nation-state in terms of technological and economic development.*[274]
- Maintain the current course . . . *passively promoting increased global dependence on global infrastructure, with the anticipated ramifications being higher likelihood of catastrophic loss of global or regional connectivity.*

Next Steps

Suggested next steps to generate momentum toward the implementation of The Recommendation include:

12-1. Governments, industry associations and academic and other research institutions should initiate strategic programs to address the current preparedness gap.

12-2. The international financial community should coordinate its plans for the case of a catastrophic loss of GUCCI.

12-3. The scientific and engineering community should publish analyses of near and long-term alternatives, highlighting promising, emerging technologies.

[274] There is an abundance of studies that correlate economic growth with ICT as an essential enabler.

Measures of Success

The successful implementation of The Recommendation can be gauged by the following measures:

Stakeholder preparedness: Stakeholders coordinate planning with international counterparts and establish procedures for catastrophic GUCCI failure. Such planning includes agreed to expectations for roles, activities and associated time intervals of each critical party.

Scholarly publications: Technically authoritative guidance is made available to the general public, government and other stakeholders regarding limitations and emerging possibilities.

Long term alternative: An acceptable back up solution is developed that offsets the existing complete dependence on GUCCI for intercontinental electronic communications.

6. SUMMARY

The ROGUCCI process introduced a fresh perspective on undersea cable infrastructure. What was new was taking a global view of all the intercontinental connectivity and treating it as an aggregate critical international infrastructure. It also charted a new course for conducting systematic research of the infrastructure's eight ingredients using the 8i Framework. This, coupled with the intrinsic vulnerability approach, enabled a comprehensive analysis of what could go wrong with GUCCI – looking beyond what had has been experienced to date. The process also went beyond the norms of association in convening the industry's technical, business and legal expertise with stakeholders and international policy change agents. This ROGUCCI "formula" played a critical role in the development of the guidance outlined in this report.

The next steps of the ROGUCCI process are the dispatch of this report and the call to the private sector, academia, nation-states and other stakeholders, to initiate the implementation of The Recommendations. The Study, Summit and Report are not designed to be limited to discussion. Rather, their intent is to have a significant impact on the reliability of GUCCI. To this end, each of the Twelve Recommendations is carefully prepared to present in concise executive fashion, the problem, recommendation, required commitment, alternatives and their consequences, benefits, next steps, and measures of success.

Both the IEEE and EastWest Institute intend to continue to serve as catalysts for mobilizing resources to implement The Recommendations. However, the challenge is for individuals, organizations and industry associations to take up and forge ahead. Early briefings of the ROGUCCI Recommendations are very encouraging, as enthusiastic responses from the private and public sector have been witnessed from six continents.[275]

The IEEE will maintain a ROGUCCI web site to provide updates on progress being made for each of The Recommendations and for members of the community to sustain online forum discussions.[276]

On behalf of the countless individuals and organizations that depend upon highly reliable, robust, resilient and secure global communications, the author wishes to express appreciation one more time to the many who have brought GUCCI to the performance level that has been so attained to date . . . and to thank in advance, the many who will step up to the challenges laid out herein to ensure that GUCCI breaks through the current limitations to achieve the new benchmark performance levels that are needed.

[275] One such briefing included a presentation to the EastWest Institute "Cyber 40", hosted at the Canadian Embassy in Washington, D.C. on the 19th of April, 2010.
[276] www.ieee-rogucci.org

7. ACKNOWLEDGEMENTS

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8. ACRONYMNS

8i	Eight Ingredient Framework for Information and Communications Technology Infrastructure
ARECI	Availability and Robustness of Electronic Communications Infrastructure Study
ASPR	Agreements, Standards, Policies and Regulations
BU	Branching Unit
BUTEC	British Underwater Test and Evaluation Centre
C	The speed of light, a constant
CQR	IEEE Technical Committee on Communications Quality & Reliability
CNI:	Critical National Infrastructure
CCTV	Closed Circuit Television
CS	Cable Ship
DCN	Digital International Switching Centre
EC	European Commission
EDFA	Erbium Doped Fiber Amplifier
EEZ	Exclusive Economic Zone
EMP	Electromagnetic Protection
ETS	Emergency Telecommunications Service
EWI	EastWest Institute
DIFC	Dubai International Financial Centre
FCC	Federal Communications Commission (U.S.)
FRB	Federal Reserve Board (U.S.)
FSSCC	Financial Services Sector Coordinating Council
FEC	Forward Error Correction
G.652	ITU recommendation number for standard single mode fiber
GETS	Government Emergency Telecommunications Service (GETS)
GUCCI	Global Undersea Communications Cable Infrastructure[277]
HF	High Frequency
ICT	Information and Communications Technology
ICPC	International Cable Protection Committee
IEPS	International Emergency Preference Service

[277] This term was introduced by the ROGUCCI process, which introduced the global aggregate perspective of the infrastructure.

IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
ISR	International Simple Resale
IRU	Indefeasible Right to Use
ITU	International Telecommunications Union
ITU-T	International Telecommunications Union – Telecommunications
LASER	Light Amplification by Emission of Radiation
MENOG	Middle East Network Operators Group
NOC	Network Operations Centre
NRIC	Network Reliability and Interoperability Council
NRSC	Network Reliability Steering Committee
NSTAC	The U.S. President's National Security Telecommunications Advisory Committee
NPE	Network Protection Equipment
PC	Personal Computer
PDH	Plesiochronous Digital Hierarchy
PFE	Power Feed Equipment
Psi	Pounds per square inch
RFS	Ready For Service
ROGUCCI	Reliability of Global Undersea Communications Cable Infrastructure
SDH	Synchronous Distribution Hierarchy
SLTE	Sub-sea Line Terminating Equipment
SMP	Significant Market Player
SONET	Synchronous Optical Network
STM	Synchronous Transport Module
TMN	Telecommunications Management Network
UAV	Unmanned Aerial Vehicle
UNCLOS	(The) United Nations Convention on the Law of the Seas
VoIP	Voice over Internet Protocol
VPN	Virtual Private Network
WDM	Wavelength Division Multiplexing
WPS	Wireless Priority Service

9. Glossary of Key Terms

Availability

Availability is simply the extent to which a system is ready to be called into use for its designated purpose, without advance knowledge of when it is needed. In The Study, the system is the global undersea communications cable infrastructure, which is the aggregation of individual long haul fiber optic undersea cable systems. A more formal definition of availability is offered as follows:

> **The degree to which a system, subsystem, or equipment is operable and in a committable state at the start of a mission, when the mission is called for at an unknown, i.e., a random, time.**[278]

Infrastructure, network or service availability characterizes the infrastructure, network or service being operable for use, as intended, at any given instant. It is a function of the underlying system(s) reliability, robustness of technology and design and reparability or restorability. Network design includes appropriate redundancy, alternate routes and sufficient or additional capacity. Availability is expressed in multiple ways, such as, the duration of time, the probability, and the percent of time, that the network is operable. Conversely, the time per interval during which the network is inoperable (i.e., unavailability) sometimes is the indirect measure of availability. The duration of (operable or inoperable) time may be continuous or non-continuous.

$$\textit{Total Time Available} = T_A = \sum T_{Operable(i)\, i}$$

$$\textit{Total Time Unavailable} = T_U = \sum T_{Inoperable(j)\, j}$$

$$\textit{Availability} = T_A \,/\, (T_A + T_U)$$

$$\textit{Unavailability} = T_U$$

where

$$T_A + T_U = \textit{Total Time Interval} = T_I$$

For example, current system platforms are commonly described as 'highly available' if they are operable at least "five-nines" (e.g., 99.999% or better). This corresponds to 5.2 minutes of cumulative inoperable or downtime, per year.

Backhaul

Connection from the landing station back to the terrestrial network.

Critical Communications Infrastructure

There are specialized Best Practices for reliability when dealing with high and ultra-high reliability systems, such as critical communications infrastructure. Because of the complex, sensitive and proprietary nature of this subject, critical communications infrastructure is generally best defined by its owners and operators. Generally, such distinction applies to points of concentration, facilities supporting high traffic, and network control and operations centers, and equipment supplier technical support centers. The first two of these criteria apply for GUCCI.

Dark fiber

Fiber that is deployed but not yet being used.

[278] ATIS Telecom Dictionary. www.atis.org

Dominant Technology Issues
Those technology issues that have the most impact on GUCCI.

Outage
A condition in which a user is completely deprived of service by the system. For a particular system or a given situation, an outage may be a service condition that is below a defined system operational threshold, i.e., below a threshold of acceptable performance.[279]

Private Circuits or Leased Lines
A point-to-point private line subscribed to by an organization to provide communications services between sites.

Reliability
Reliability is simply the likelihood that a system will perform its intended function within the context it was designed to operate within.[280]

A measure that refers to a particular "mission." It represents the ability of the system, subsystem, equipment, network, or service to operate for the intended purpose, during the intended period of time. It is the probability that given operability now, it sustains operation for a period of time. For example, the reliability of the space shuttle would refer to it's operability during the period of time that includes its launch, time in space and return to Earth. Thus, reliability is often characterized as a probability or percent or may also be characterized as the Mean Time Between Failure (MTBF).

The ability to achieve high availability is also a factor of how quickly a system, subsystem, equipment, network, or service can be repaired or service restored when a failure occurs. Reparability or Restorability are respectively characterized by the Mean Time To Repair or Mean Time To Restore (MTTR). First and foremost is the return to operability of the intended function. This may occur through an equipment repair, or more likely an equipment substitution, redundancy or alternate means for the intended use. Hence, in communications infrastructure, Mean Time to Restore (service) is most often the key measure.

Robustness
Robustness is the property of being strong and healthy in constitution.[281] It is further defined as a condition of a system design "that remains relatively stable, with a minimum of variation, even though factors that influence operations or usage, such as environment and wear, are constantly changing."[282] Robustness is the degree to which a system or component can function correctly in the presence of invalid inputs or stressful environment conditions.[283]

Other definitions vary in (a) the emphasis they place on where the challenges come from - internal (e.g., component failure) or external (e.g., environmental), (b) the degree to which such challenges are anticipated - ranging from conditions slightly beyond what is expected to anything unexpected, and (c) the level of stability of functionality maintained during the period of stress. For the purpose of The Study, the robustness of undersea communications cable infrastructure includes:

- the ability to maintain critical functions, but not all functions
- in the context of both internal and external challenges
- when the challenges are of any degree of variability from expected conditions, but that expectations should diminish with increased stress (e.g., a more robust system can handle more extreme forms of stress)

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[279] ATIS Telecom Glossary 2000, T1.523-2001, www.atis.org/tg2k/
[280] A more formal definition from the ATIS Telecom Glossary. reliability: 1. The ability of an item to perform a required function under stated conditions for a specified period of time. 2. The probability that a functional unit will perform its required function for a specified interval under stated conditions. 3. The continuous availability of communication services to the general public, and emergency response activities in particular, during normal operating conditions and under emergency circumstances with minimal disruption.
[281] wordnet.princeton.edu/perl/webwn.
[282] www.onesixsigma.com/tools_resources/glossary/glossary_r.php
[283] Institute of Electrical and Electronics Engineers. IEEE Standard Computer Dictionary: A Compilation of IEEE Standard Computer Glossaries. New York, NY: 1990.

Sector
A group of industries or infrastructures that perform a similar function. In general, critical sectors are sectors whose incapacitation or destruction would have a debilitating impact on the national security and the economic and social well-being of a nation.[284]

Shared Ownership
Cable consortia share the ownership of cable systems and have agreements about how capacity usage will be shared.

Shunt Fault
A condition where the cable system has sustained damage to its protection insulating sheath, but is still able to maintain potential to continue operating. The virtual earth position is established at the damaged location. Repairs need to be conducted rapidly, because a second damaged location would mean a loss of potential, resulting in an outage.

Threat
A threat is an attempt to exploit one or more vulnerabilities that may result in damage to, or compromise of, a system (e.g., GUCCI), or some portion of it.[285]

Vulnerability
A vulnerability is an intrinsic characteristic of an infrastructure or system (e.g., GUCCI or its components) that make it susceptible to damage or compromise if exploited by a threat.

[284] International Critical Information Infrastructure Protection (CIIP) Handbook 2004, , An Inventory and Analysis of Protection Policies in Fourteen Countries, Swiss Federal Institute of Technology, p. 227. Network Reliability and Interoperability Council VI, Homeland Security – Physical Security (Focus Group 1A) – Prevention and Restoration Report, Issue 2, Mar. 2003, pp.27, 41, www.nric.org/fg/nricvifg.html; Network Reliability and Interoperability Council VI, Homeland Security – Physical Security (Focus Group 1A) – Final Report, Issue 3, Dec. 2003, www.nric.org/fg/nricvifg.html; Network Reliability and Interoperability Council VII, Focus Group 3A – Wireless Network Reliability – Final Report, Issue 3, Sept. 2005, www.nric.org/fg/index.html; Network Reliability and Interoperability Council VII, Focus Group 3B – Public Data Network Reliability – Final Report, Issue 3, Sept. 2005, www.nric.org/fg/index

[285] Network Reliability and Interoperability Council VI, Homeland Security – Physical Security (Focus Group 1A) – Prevention Report, Issue 1, Dec. 2002, p. 27, www.nric.org/fg/nricvifg.html;

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APPENDIX A. Analysis of Recent Major Outage Events

Undersea communications cable systems are designed to be highly reliable, their permitted downtime measured in terms of seconds per system-year. These ultra-high levels of reliability engineering for such communications systems are attempted in only a few human endeavors; other examples being the nuclear, aviation and outer space disciplines.[286] For this reason, the advanced skills and methodologies used are uncommon.

Even so, network outages occur. When system failures occur, traversing payload is impaired. When alternate paths are available, the payload may be re-routed automatically, or through manual means, but because there are limited routes available, re-routed traffic may take longer paths, which introduces latency.

Because of vast distances and limited routes available, re-routed traffic may take paths with noticeable delays for applications with extreme sensitivity, such as competitive real-time financial transactions. Such delays may be unacceptable.

Outage detection happens instantly, as signals travel at the speed of light. On the other hand, repair times can be quite lengthy. Some repairs – such as those associated with hardware replacement to landing station endpoints, power distribution equipment on shore, or software changes - can be routinely handled in durations similar to what is involved in terrestrial network maintenance, typically measured on the order of hours. However, repairs and maintenance on the open seas are not so easy and are measured on the order of weeks. Here, repair times involve many critical steps – missing any one of them can jeopardize the entire repair operation. Thus the objective is to accomplish the mission in as little time as necessary, but to also execute in a way that ensures the highest probability of getting the job done right the first time. The process begins with a pre-repair meeting where planning and resource estimation is performed with all of the parties involved. As the most time in the process can be lost in the grapnel attempts for the cable, assembling all possible data that can support an accurate location is essential to avoid lengthy location searches. Grapnelling close to fault location is key to reducing time. Experienced crews know that it is also worth conducting research to determine which methods have been successful in past repair activities in the area. Selective use of remotely operated unmanned vehicles can optimize repair time. If possible, simultaneously recovering the stray end while testing the system cable end can save time. It is also important to have competent staff available on a 24-hour by 7-days per week basis.

A.1 Recent Major Outages

Most undersea communications cable outage events are not reported to the public. The reasons for protecting this information include protecting competitive interests (i.e. disclosing a system failure is viewed as having a net downside affect on business) and for protecting the security interests of the nation-state and private sector stakeholders associated with the cable system.[287] For these reasons outage data can be hard to come by. Most outages that are reported within the public domain have had a public impact such that some industry reporting becomes necessary. But that is the exception. Analysis was

[286] Communications systems that are deployed in public networks are routinely designed for 5 9's (99.999% availability); in the mid-1990's the 5 9's barrier was broken when the 5ESS Switch achieved the first sustained 6 9's performance in public networks; this same system went on to break the 7 9's barrier. Analysis of FCC ARMIS 43-05 data, BPI TelcoData.
[287] These reasons for outage data protection are similar to those in the terrestrial-based networks. Discussion around these points can be found in the proceedings of the ATIS Network Reliability Steering Committee (NRSC) and the FCC's Network Reliability and Interoperability Council (NRIC).

conducted of *publicly available information* on communications cable outages. In addition, insights were gleaned from *proprietary outage databases* through discussions with experts. These discussions were conducted in a way that protects the sensitive aspects of the data, yet supports the research objectives of The Study. For example, outage analysis conclusions drawn from the research are able to confirm that both data sources found similar relative proportions among the identified causes (e.g., fishing, anchors).

A.1.1 Survey of Events

The analysis described above covered over 600 outage events. The time period was limited to the last decade, keeping the types of systems relatively similar technology-wise. Further summary of the outage data can be outlined as:

- Outages were included from each region where cable systems are deployed
- Outages were included from all cause types – man-made and natural
- Outages were included from any system or network operator
- Outages were included from any equipment supplier

A.1.2 Pareto Analysis of Cause Attribution

Outages can be caused by the failure of any of the eight ingredients, which can happen when a threat is able to exercise one or more intrinsic vulnerabilities. Thus, cable systems can experience outages due to causes associated with Power, Environment, Hardware, Software, Network, Payload, Human or Policy. Most major cable system outages have occurred due to causes associated with the Environment and Hardware ingredients. This can be expected given the special challenges for these two areas. The Environment consists of thousands of kilometers of distance in harsh, untamed undersea terrain. The destruction of a cable system's Environment is typically associated with undersea earthquakes or landslides, though marine life and abrasion are also contributors. Similarly, the Hardware deployed for these vast distances consists of continuous, highly purified strands of fibers wrapped in a protection package on the order of the size of a household garden hose. Physical destruction of cables, or cable cuts, occurs most frequently as the result of being hooked by fishing equipment or a ship's anchor.

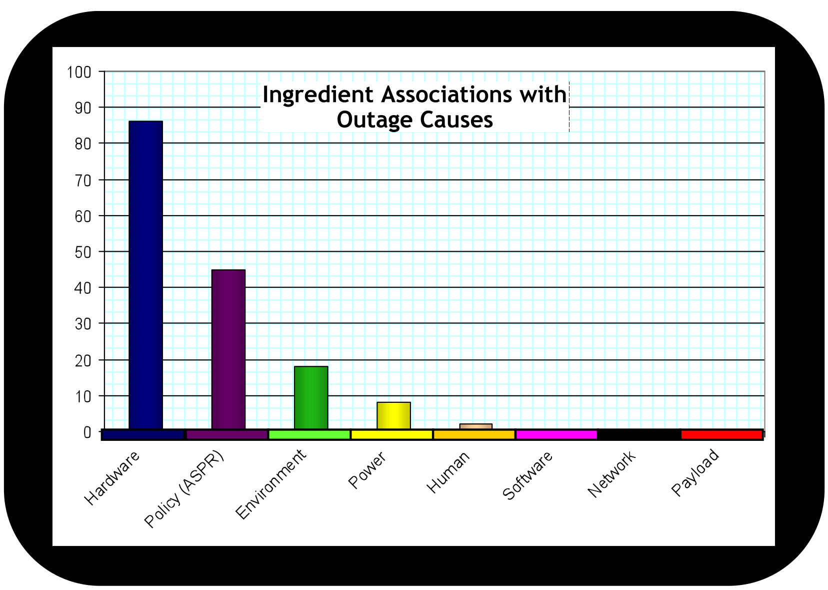

Figure 33. Pareto Analysis of Ingredient Associations with Outage Causes (%)

A Pareto analysis is presented in Figure 33. The methodology applied defines an ingredient category as a contributor if a threat exercised one of its intrinsic vulnerabilities. Thus for a single outage event, there may be more than one ingredient involved. Examples of this include an earthquake altering the *Environment* and damaging the *Hardware*; or a fishing crew being unmotivated by *Policy* enforcement limitations regarding restricted zones and damaging *Hardware* with their trawling equipment. It is readily apparent from the chart that a few ingredients are involved to a large extent and the remaining ingredients to a minimal extent. An encouraging observation of the Pareto analysis is that nearly half of the events could potentially be prevented because of the association with something within human control: agreements, standards, policies and regulations - i.e. the "Policy" ingredient.

A.2 The Historically Common vs. Very Low Probability Events

The Pareto analysis just presented depicts a situation where a few categories have been associated with nearly all of the problems. However, it is vital to realize that each of the ingredients has intrinsic vulnerabilities that are always there. While the diligence and vigor that the industry has applied to learning from the historical events is highly commendable and needs to continue with ever increasing fervor, something must be said for the *very low probability* - yet possible - types of events that have *very high impact*. Figure 34 provides a simple depiction of the situation.

Given the ever-increasing global dependence on undersea communications cable infrastructure, the effects of a widespread (i.e. global or regional) outage would be history-altering. The profound reality that such events can occur needs to be effectively communicated to stakeholders and decision makers so that effective countermeasures can be developed and deployed to mitigate the impacts of such events. The *Countermeasure Approaches* section below outlines some insights into such opportunities.

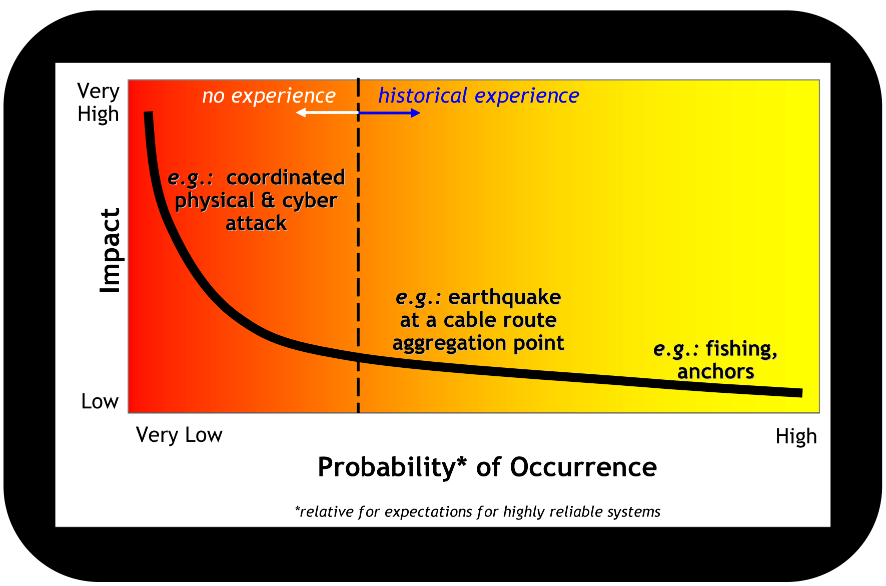

Figure 34. Portrayal of the High Probability Low Risk vs. Very Low Probability Very High Risk Events

A.3 Intrinsic Vulnerability Analysis of Select Recent Events

This section will provide further analysis of the four most significant outage events in recent history. These outages are:

- 2006 (December 26) Luzon Strait [Hengchun Earthquake] – multiple cuts
- 2008 (January 23 – February 4) Middle East – multiple cuts
- 2008 (December 19) Mediterranean Sea – multiple cuts
- 2009 (August 12 and 17) Luzon Strait [Typhoon Morakot and Taiwan Earthquake] – multiple cuts

Various reports are available in the public domain for each of these events. The focus of these reports is on the threats involved. For the first and fourth events listed above, there is consensus on the threats that caused the outages; for the middle two events, there is less certainty regarding the threats that caused the outages.

In contrast to the spotlight of these public reports being on the effective threats, this analysis focuses on the intrinsic vulnerabilities of the critical infrastructure – the susceptibility that was acted upon. The value proposition for this approach is that it provides insights and guidance that are based on the foundational scientific and engineering principles that are the basis of the infrastructure, and in which there can be very high confidence relative to some of the threat-based analyses.

A.3.1 Cause-Effect Analysis

A Cause-Effect, or Ishikawa, diagram is shown in Figure 35.

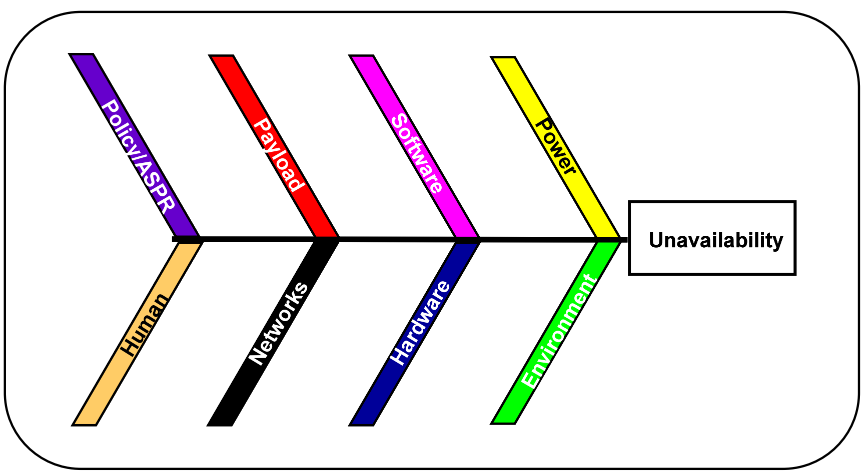

Figure 35. Ishikawa Diagram with 8i Framework.

Hengchun Earthquake (2006)

The Hengchun earthquake occurred on Tuesday, December 26 at 12:25 UTC, having an epicenter in the Luzon Strait (21.89°N 120.56°E).[288] Particular aspects of the island of Taiwan contributed to a unique situation. These factors include the landslides near two tectonic plates (Eurasian and Philippine), river systems that deposit exceptional debris near their entry into the sea, and the resulting turbidity current flows.[289] The Hengchun turbidity current flowed a distance of over 300 km and reached speeds on the order of 20 km/hr.

The earthquake resulted in catastrophic, global outages of historic proportions in the communications industry. This exceptional impact was due to multiple undersea cables being damaged, including:

- December 26+: 2 systems[290]
- December 27+: 2 additional systems

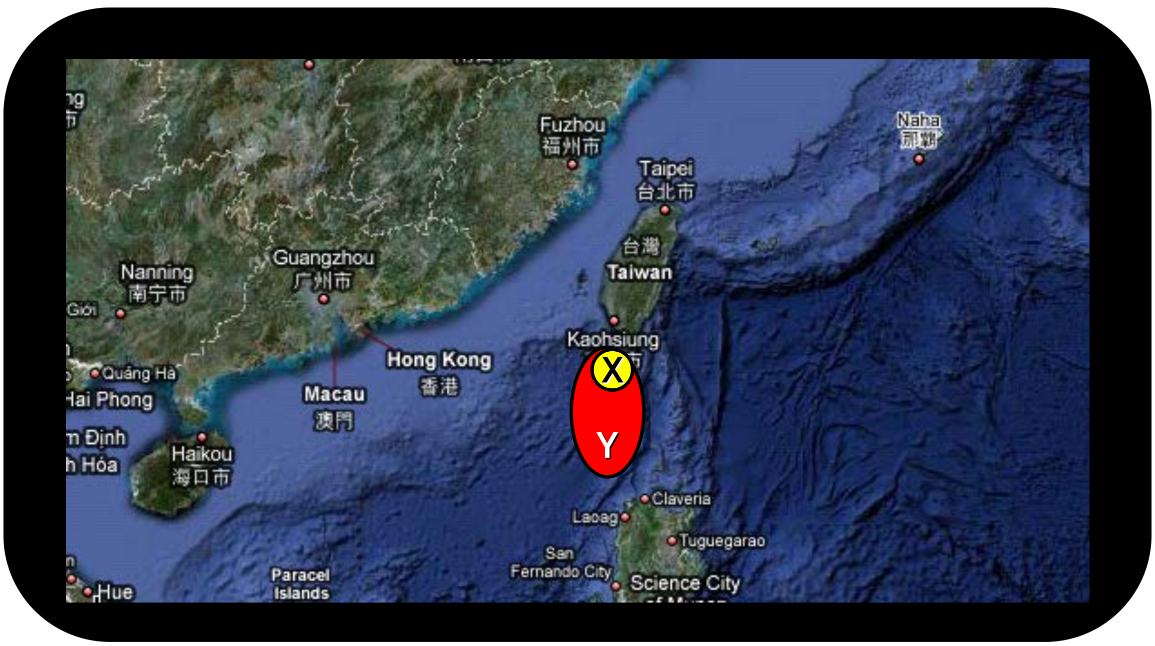

Figure 36. Hengchun Earthquake Catastrophic Outage (2006): (X) Hypocenter, and (Y) Region of Undersea Landslides and Turbidity Current Flows

The affected regions include Taiwan, China, Hong Kong, Vietnam, Japan, Philippines and Singapore and many other regions around the world (e.g., United States and Europe). The affected services include substantially reduced international connectivity for telephone voice traffic, Internet access including email and search capabilities, financial sector and other commerce traffic, and other critical services.

[288] The magnitude of the earthquake has been rated as 6.7, 7.1 and 7.2 by the Central Weather Bureau (Taiwan), United States Geological Survey, and the Japan Meteorological Agency, respectively.
[289] Turbidity currents are forces of sediment-dense water that moves within another fluid of lower density. Because the speed of the turbidity current increases with its density, these currents can increase their speed as they create erosion and pick up more debris.
[290] While the identifies of these systems is readily available in the public domain, it is not necessary to mention specific system names in this Report.

The duration of the impact extended to approximately 2 months. Numerous specialized undersea communications cable vessels were deployed in the repair operation to restore the damaged cables to service.

As shown in Figure 37, the Hengchun earthquake threat exercised the intrinsic vulnerability of the undersea environment by violently altering it. This dramatic altering of the previously safe Environment, became a threat that exercised the intrinsic vulnerability of Hardware to be physically damaged. From a global infrastructure perspective, the aggregated routing of different cables through the Luzon Strait exposed the intrinsic vulnerabilities of Networks to be accessible and to have points of physical failure. The reasons for lack of physical diversity appear to be, in part, geopolitical restrictions on the use of other routes, exposing the intrinsic vulnerability of Policy to be lacking sufficient agreements.

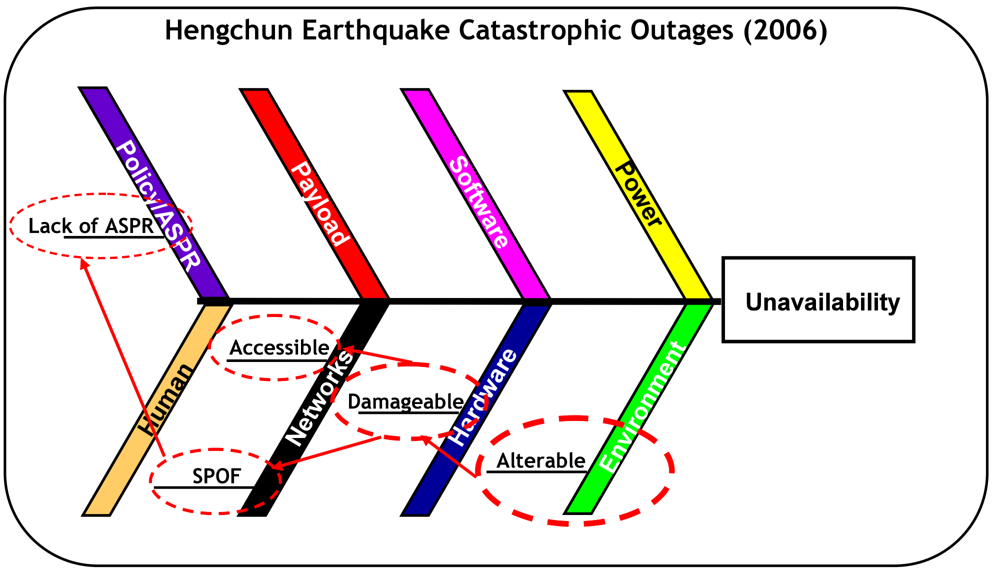

Figure 37. Hengchun Earthquake 8i Ishikawa Analysis

Middle East (2008)

Multiple undersea communications cable cuts occurred in the Middle East region during the 12-day period of January 23 through February 3. There is not consensus as to the actual threats that damaged the cables.[291] This uncertainty has fostered intrigue, which, coupled with the ongoing political conflict of the region and the widespread impact of these cuts, resulted in unprecedented traditional news media coverage and Internet forum discussion activity for a communications outage. Several official government and industry expert views have attributed some of the cable cuts to anchors. Participants of the ROGUCCI Global Summit were able to tour one of the repair vessels used in the restoration process. Further, these participants were able to learn from the crew of this ship what they observed. Insights were provided that substantiated the cause as anchor damage from ships that were drifting due to unusually high winds in the region at the time.

[291] The causes of these outages have been ascribed by different sources to: dragging ship anchors, non-anchor maritime activity, bad weather, an earthquake, a coordinated non-government organization attack (NGO), a government-sponsored activity using explosives, as well as others.

The cables damaged include:

- January 23+: one system
- January 30+: two additional systems affected (one was an additional segment of the initial system)
- February 1+: an additional segment of one of the above systems
- February 3+: one more system affected

In addition, on February 4, it was discovered that one of the systems had been damaged again, this time farther East near Penang, Malaysia.

Figure 38. Middle East Catastrophic Outage (2008)

The countries most impacted include Afghanistan, Bahrain, Bangladesh, Egypt, Kuwait, India, Pakistan, Qatar, Saudi Arabia, and the United Arab Emirates, and effects were felt throughout the rest of the world (including the United States and Europe). Impaired services include substantial reduced international connectivity for telephone voice dialing and Internet access including email and search capabilities, financial sector and other commerce traffic, and other critical services.

In addition to the reliability impacts described above, if the events were a coordinated malicious activity there could be security issues that arise from the rerouting of traffic. The practice of cutting communications cables to achieve a strategic advantage has been a practice for more than 100 years.[292]

[292] Cable Cutting in War Time, The Pall Mall Gazette, May 11, 1898

Numerous specialized undersea communications cable vessels were deployed in the repair operation to restore the damaged cables to service.

As shown in Figure 38, the multiple locations of the cable damage were focused in two primary areas: Alexandria, Egypt and the perimeter of the U.A.E. Unlike the Henchung earthquake, these damages occurred in geographically separated areas, though they were within the same region.

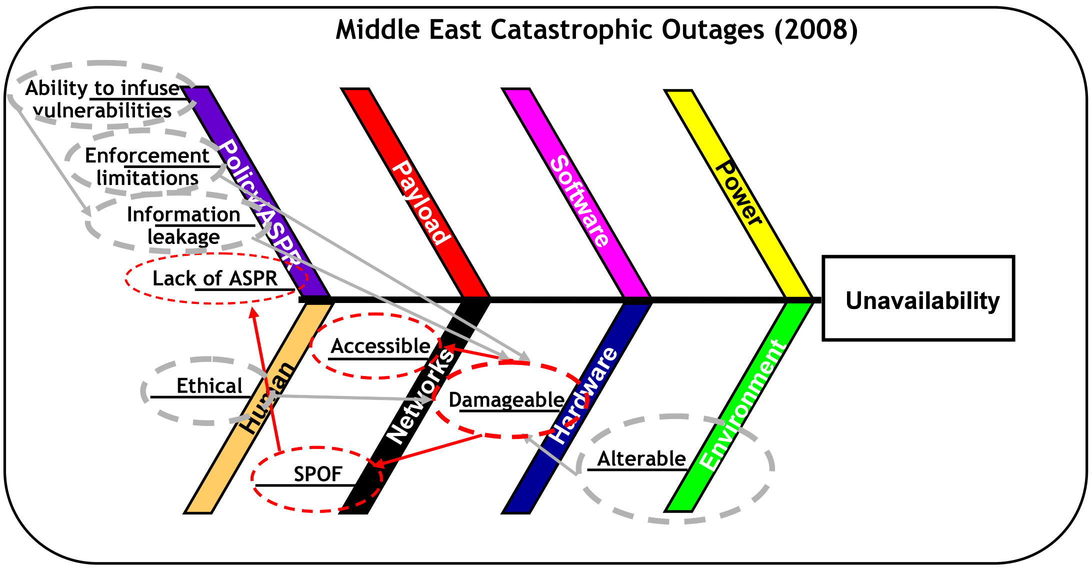

Figure 39. Middle East Multiple Cuts 8i Ishikawa Analysis

If the triggering threat was a natural phenomenon (i.e. an earthquake) for any of these damage areas then the intrinsic vulnerability of alterability of the undersea Environment was exercised. In this scenario, the dramatic altering of the previously safe Environment became a threat that exercised the intrinsic vulnerability of Hardware to be physically damaged. If the threat was a ship anchor, then the same intrinsic vulnerability of Hardware was exercised. Though ship anchors are a known threat to undersea communications cables, and various Policies are in place to avoid anchor damage, the ASPR intrinsic vulnerability of enforcement limitations permits continuous exposure of cables. A more complicated scenario involves directed action by Human actors. This scenario could involve Human agents within the infrastructure, who are susceptible to the intrinsic vulnerability of ethical compromise. This could be associated with coercion, greed, malicious intent or other motivations. The Human agents could have compromised privileged information regarding the cable infrastructure. However, as shown elsewhere in The Report, with the abundance of critical communications cable infrastructure information available on the Internet, privileged information would not be necessary. Such information exists in the public domain due to the intrinsic vulnerability of information leakage that is part of ASPR processes. This information leakage is itself propagated by the intrinsic vulnerability of ASPR to infuse vulnerabilities (i.e. requirements for information to be part of an open proceeding).

From a global infrastructure perspective, the predominant aggregated routing of Europe-Asia through the Red Sea passage exposed the intrinsic vulnerabilities of Networks to have points of physical failure and to be accessible. Analysis of the reasons for the lack of physical diversity appear in part to geopolitical restrictions, exposing the intrinsic vulnerability of Policy to be lacking sufficient agreements.

Mediterranean Sea (2008)

Multiple undersea communications cable cuts occurred in the Mediterranean Sea on December 19. The cable damage has been attributed to fishing trawler activity, ship anchors, an earthquake or a combination of these. The cables damaged were:

- January 19+: four systems affected

Figure 40. Mediterranean Sea Catastrophic Outage (2008)

The regions most affected include northern Africa, the Middle East and the Indian subcontinent, and Europe, while the rest of the world (including the United States and Asia) was also affected. The most seriously affected countries were (in order) Egypt, Saudi Arabia, Maldives, Bangladesh, Sri Lanka, Sudan, U.A.E., Lebanon, Pakistan and India.[293] Impaired services included substantially reduced international connectivity for telephone voice dialing and Internet access including email and search capabilities, financial sector and other commerce traffic, and other critical services. Most business-to-business traffic between Europe and Asia was rerouted through the U.S.

Specialized undersea communications cable vessels were deployed in the repair operation to restore the damaged cables to service.

[293] Based on the percentage of total routed prefixes per country. *Deju Vu all Over Again: Cables Cut in the Mediterranean*, Alin Popescu, December 2008.

As shown in Figure 40, the multiple incidents of cable damage were contained within a single geographic area: between Sicily and Tunisia. Like the Henchung earthquake, these damages occurred in a geographically concentrated area, though the attribution to an earthquake is not clear.

If the triggering threat was a natural phenomenon (i.e. an earthquake), then the intrinsic vulnerability of alterability of the undersea Environment was exercised. As before, the dramatic altering of the previously safe Environment became a threat that exercised the intrinsic vulnerability of hardware to be physically damaged. If the threat was a ship anchor, then the same intrinsic vulnerability of Hardware was exercised. Though ship anchors are a known threat to undersea communications cables, and various Policies are in place to avoid anchor damage, the ASPR intrinsic vulnerability of enforcement limitations permits continuous exposure of cables. This holds similar for fishing practices that may have damaged the cables.

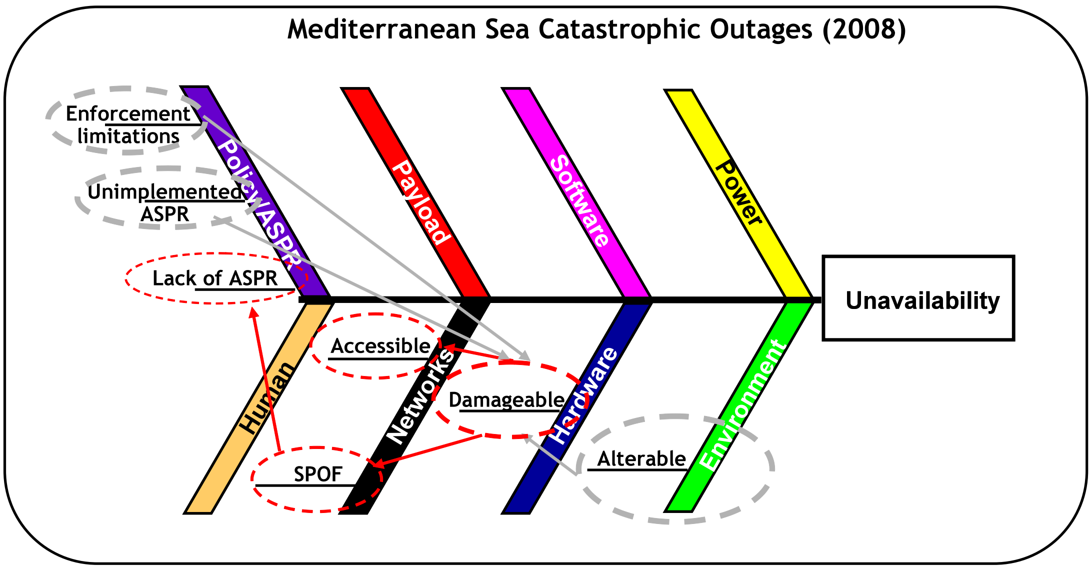

Figure 41. Mediterranean Sea Multiple Cable Cuts 8i Ishikawa Analysis

Typhoon Morakot and Taiwan Earthquake (2009)

Deep sea landslides caused by the approach of Typhoon Morakot severed undersea cables and disrupted telecommunications and Internet traffic to China and various areas of Southeast Asia. This impact was due to multiple undersea cables being damaged, including:[294]

- August 9: 3 systems
- August 12: 5 additional systems
- August 17: 1 additional system

The affected regions include China, Singapore, the Philippines and Hong Kong. Traffic was rerouted to back-up cables, however there was concern that the back-up cables would not be able to handle all of the traffic.[295]

[294] *Hong Kong Rebounding from Recent Natural Disasters Typhoon Morakot and Earthquake in August, 2009*, HKCOLO, October, 2009.

Figure 42. Typhoon Morakot and Taiwan Earthquake Catastrophic Outage (2009): (9)(12) progression of typhoon, and (17) Earthquake

On August 17th, an earthquake off the east coast of Taiwan, amidst the Southwestern Ryukyu Islands (Japan), damaged the cables being used as back-up. In all, nine undersea cables were damaged by the typhoon and the earthquake, affecting service between the Chinese mainland and Taiwan, Japan, the Republic of Korea, Singapore, the United States, and Europe.[296]

As shown in Figure 43, Typhoon Morakot and the Taiwan earthquake threat exercised the intrinsic vulnerability of the undersea environment by violently altering it. This dramatic altering of the previously safe Environment, became a threat that exercised the intrinsic vulnerability of Hardware to be physically damaged. From a global infrastructure perspective, the aggregated routing of different cables through the Luzon Strait exposed the intrinsic vulnerabilities of Networks to be accessible and to have points of physical failure. The reasons for lack of physical diversity appear to be, in part, due to geopolitical restrictions on the use of other routes, exposing the intrinsic vulnerability of Policy to be lacking sufficient agreements.

295 http://www.computerworld.com/s/article/9136622/Typhoon_Morakot_severs_three_undersea_Internet_cables

296 http://english.peopledaily.com.cn/90001/90781/90877/6731967.html

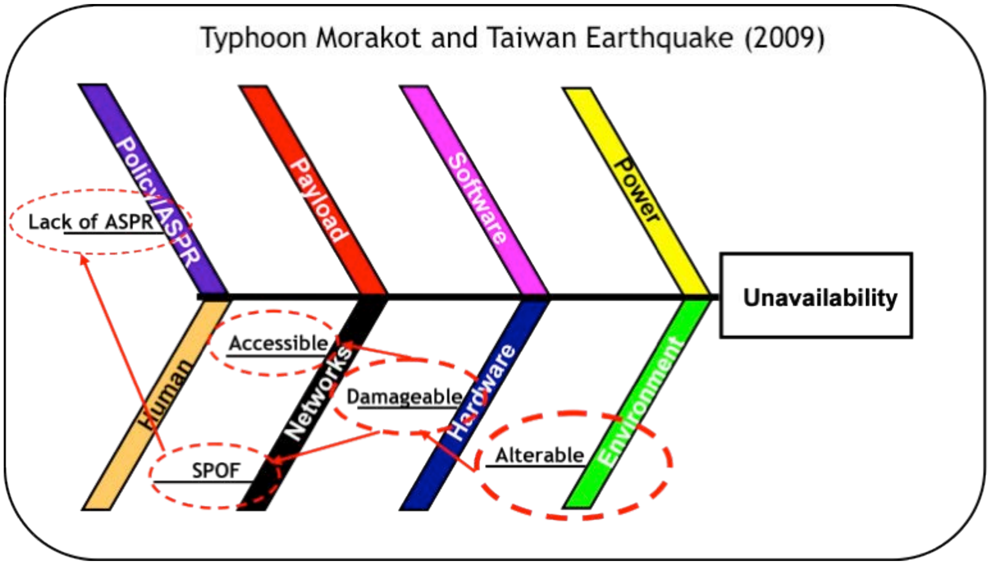

Figure 43. Typhoon Morakot and Taiwan Earthquake 8i Ishikawa Analysis

A.3.2 Countermeasure Approaches

Given that intrinsic vulnerabilities are ever present in the undersea communications cable infrastructure, it can be helpful to explore methods that can address their exposure and ability to be exercised by a threat in order to prevent future similar occurrences or ameliorate the impact of future similar occurrences. Amelioration of impact can be accomplished by reducing the breadth of the impact in terms of impaired users, by reducing the duration of the outage event, or by reducing the criticality or types of services affected.

Tables 8, 10 and 11 provide a countermeasure analysis for each of the four outages presented above. This countermeasure analysis is not complete, but is offered to demonstrate the challenges faced in raising the overall resilience of the undersea communications cable infrastructure and the cross-disciplinary nature of countermeasures (e.g., a Hardware limitation may be addressed by a Policy countermeasure). Note that for those cases where this analysis was conducted for events with an unconfirmed threat, the analysis was completed as if any of the suggested countermeasures were applicable.

Table 8. Hengchun Earthquake 8i Countermeasure Analysis

Infrastructure Ingredient	Exercised Intrinsic Vulnerability	Countermeasure Considerations	CM Potential to Prevent Future Similar Occurrences	CM Potential to Ameliorate Impact of Similar Occurrences
Environment	Alterable	*Luzon Strait is known tectonic risk*	X	X
Power				
Hardware	Damageable	*Physical protection against these forces not feasible*		
Software		*Automatic reroutes*		X
Network	Accessible SPoF	*Provide physical diversity*	X	X
Payload				
Human				
Policy (APSR)	Lack of ASPR	*Remove geopolitical restrictions*	X	X

Hengchun Earthquake

Regional geopolitical forces funnel all of the cable routes that connect North America to the regional financial hubs of Hong Kong and Singapore through the Luzon Strait. This situation stresses the intrinsic vulnerability of networks having single points of physical failure. To address this, progress in the ASPR arena can help tremendously. Specifically, if agreements could be made to permit the laying of undersea communications cables in the North-South direction in between mainland China and Taiwan, then a geographical separation can be achieved and thus reduce the exposure of the aggregate global infrastructure to this seismically active area. Other enhancements can be accomplished via software capabilities and pre-arranged contractual agreements that would enable more speedy and high capacity reroutes.

Given the reality of geographic regions of frequent high magnitude earthquakes (Figure 44), a global review of infrastructure single points of geographic failure is highly relevant. Surely individual system planners and designers appreciate this concern. However, the exposure of aggregated worldwide communications resources is a problem at another level. The increasing dependence of the world's economic stability, as well as other interests, require that geopolitical limitations be revisited with the mutual interests of affected parties in mind.

Table 9. Frequency of Earthquakes Worldwide[297]

Magnitude	Annual Frequency
2 to 2.9	~1,300,000*
3 to 3.9	~130,000*
4 to 4.9	~13,00*0
5 to 5.9	1319**
6 to 6.9	134**
7 to 7.9	17***
8 and higher	1***

* estimates
** based on observations from 1990 onward
***based on observations from 1900 onward

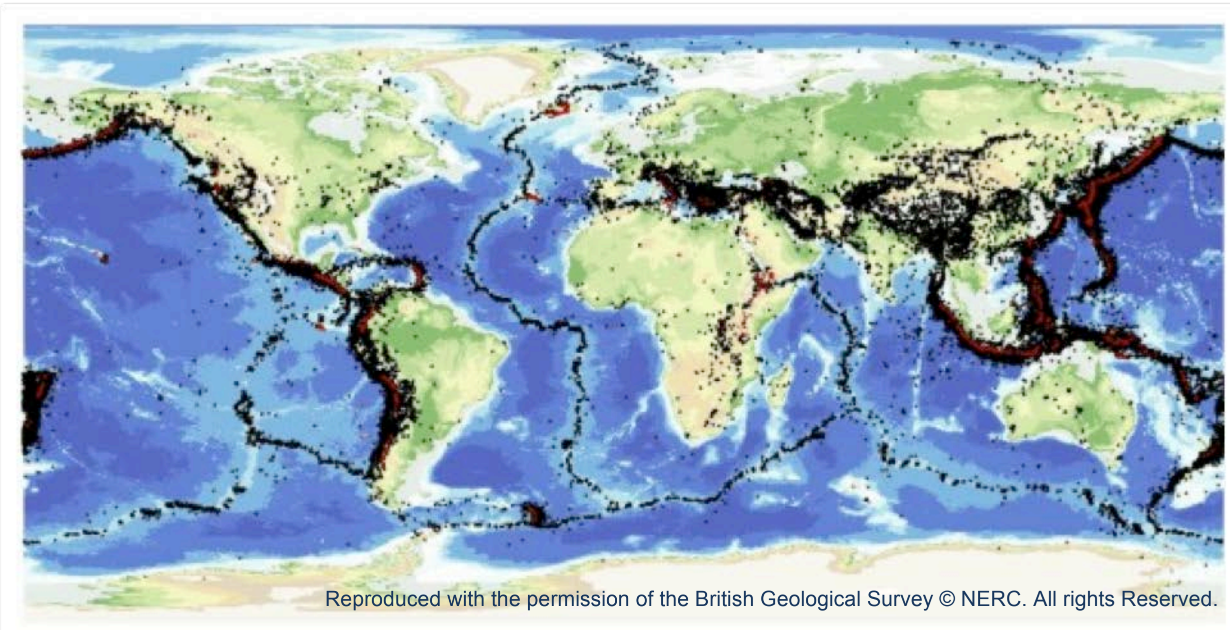

Figure 44. Earthquake Belts of the World[298]

Middle East and Mediterranean Multiple Cable Cuts

It is unclear as to whether a sufficient post-mortem analysis has been completed, particularly for the Middle East events. Due to the uncertainty of the actual threats that caused these cuts, available analyses are somewhat limited. The analysis below, while remaining flexible for this uncertainty, provides guidance in key areas that can prevent similar occurrences and ameliorate the impact of similar events.

[297] Data from the United States Geological Survey (www.usgs.gov).
[298] Data from the British Geological Survey, National Environment Research Council, www.bgs.ac.uk

Table 10. Middle East Multiple Cable Cuts 8i Countermeasure Analysis

Infrastructure Ingredient	Exercised Intrinsic Vulnerability	Countermeasure Considerations	CM Potential to Prevent Future Similar Occurrences	CM Potential to Ameliorate Impact of Similar Occurrences
Environment	Alterable	*Few undersea cable path options in this area*		
Power				
Hardware	Damageable	*Physical protection against these forces not feasible*		
Software		*Automatic reroutes*		X
Network	Accessible SPoF	*Provide physical diversity*	X	X
Payload				
Human	Ethical	*Address motivation; raise security*	X	
Policy (APSR)	Lack of ASPR Information leakage Enforcement limitations Vulnerabilities infusion	*Remove geopolitical restrictions;* *Back-up routing;* *Anticipate utilization;* *Strengthen ASPR;* *Educate policy makers;*	X X X 	 X X X X

Table 11. Mediterranean Sea Multiple Cable Cuts 8i Countermeasure Analysis

Infrastructure Ingredient	Exercised Intrinsic Vulnerability	Countermeasure Considerations	CM Potential to Prevent Future Similar Occurrences	CM Potential to Ameliorate Impact of Similar Occurrences
Environment	Alterable	*Few undersea cable path options in this area*		
Power				
Hardware	Damageable	*Physical protection against these forces not feasible*		
Software		*Automatic reroutes*		X
Network	Accessible SPoF	*Provide physical diversity*	X	X
Payload				
Human	Ethical	*Address motivation; raise security*	X	
Policy (APSR)	Lack of ASPR Unimplemented ASPR Enforcement limitations	*Remove geopolitical restrictions;* *Back-up routing;* *Strengthen ASPR* *Strengthen ASPR*	X X X	 X X X

In summary, countermeasures can be asymmetrical to the failure domain associated with the outage cause. Given that subject matter experts and responsible parties have limitations with regard to their expertise and responsibilities respectively, effective cross-discipline countermeasure proposal and development is often insufficiently practiced in many fields. For example, a network design expert well aware of the limitations of the geopolitical status quo, is not likely effective at having influence in that arena, despite the fact that he may be well armed with a profound economic and commercial value proposition. A key distinction of the ROGUCCI process was to integrate technical expertise, business leaders, stakeholders and international policy change agents in order to be able to aggregate the maximally useful core competencies to develop and deploy countermeasures.

APPENDIX B. Survey of Publicly Available Information

While undersea communications cable infrastructure is a highly specialized field, there exists a significant amount of information available to the public. This appendix summarizes the types of information available to the public – with examples - in 10 key areas:

1. History
2. Technology
3. Suppliers
4. Cable Systems
5. System Owners and Operators
6. Cable Landing Sites
7. Cable Routes
8. Outage Events
9. Restoration Procedures
10. Financial Dependencies

The information described below is available from published documents and the Internet.

B.1 History

The history of the world's undersea (or submarine) communications cable infrastructure is well documented. The industry has done an excellent job in documenting the trials and outcomes, events and dates, discoveries and improvements, and business risks and successes. For example, the inaugural message sent across the first trans-Atlantic cable from Queen Victoria to U.S. President Buchanan: "*England and America are united. Glory to God in the highest and on Earth, peace, good will to men.*" The message was sent as a telegraph that took over 30 hours to transmit.

Figure 45. Preservation of the History of Undersea Cables
(a) A Map of the First Trans-Atlantic Telegraph Cable Route (1858)
(b) "Eighth Wonder of the World" painting commemorating the cable crossing of the Atlantic Ocean (1866)

The Smithsonian Institute in Washington, D.C. has previously displayed an exhibit featuring the history and advances of undersea communications cable technology. The exhibit now takes on the form of an online library. The advances of undersea communications cable progress continues to be documented and includes the latest information sharing approaches - web blogs and interactive videos.

B.2 Technology

Very complete information is available to the public on the underlying science of undersea communications cables systems. The engineering design principles and many operational practices are likewise readily available, some even in the form of instructional videos. Figure 46 outlines the types of information available. Note that this spans the development lifecycle from research through manufacturing to operation.

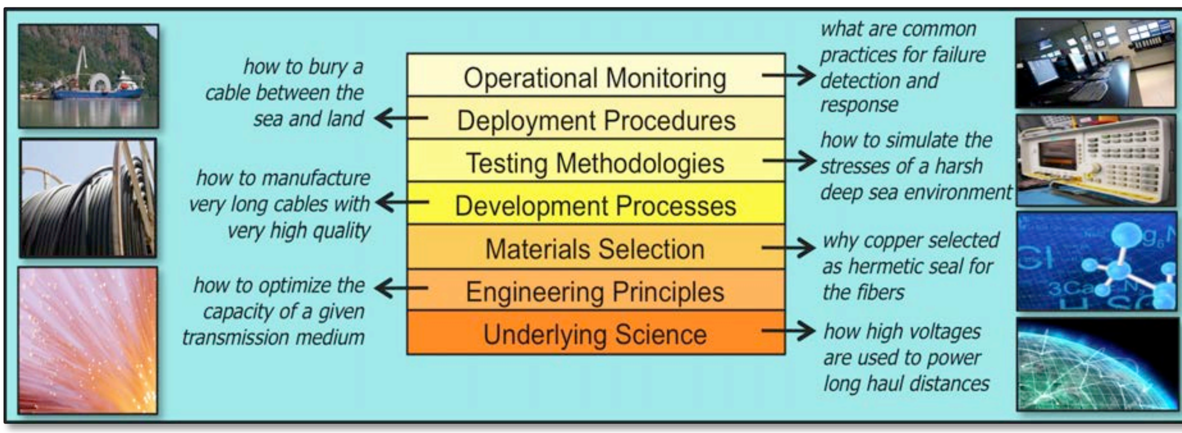

Figure 46. Maturity Model of Undersea Communications Cable Technology Information

Literally thousands of pages of information are available on these subjects. Specific examples of technology information include the principles of light and wave theory from physics that form the basis of optical fiber transmission, the trade-offs made in cable design construction, the reason for selecting particular materials for specific applications, the method of manufacturing long haul cables, techniques for field experiments to validate the predicted longevity of undersea components, the machinery and manner of digging trenches for buried cable segments, and steady state operation.

B.3 Suppliers

The suppliers of the world's undersea communications cable infrastructure are easily identified in publicly available information. To varying degrees, information is available on such areas as their:

- Technology
- Manufacturing methods
- Manufacturing locations
- Customers
- Contract wins that identify the system to be built

B.4 Cable Systems

A list can be compiled from the Internet that contains over 300 international undersea cable systems. The information available includes the system name and the systems landing points.

B.5 System Owners and Operators

Undersea cable systems have several ownership structures. In some cases, the owner is also a communications company and also an operator. In other cases, the cable system owner leases the transmission facilities to multiple communications companies that are service providers. Public domain information includes owners of currently operational undersea cable systems and their respective nationality.

B.6 Cable Landing Sites

Significant information is available to the public on undersea cable landing stations. This information includes various tutorials on the function of a landing station facility, diagrams of facility locations relative to the adjacent body of water, criteria for site selection, and geographical coordinates. An instance was found where the type of security being employed at a site is discussed. Photographs can be found on the Internet of cable landing sites that include aerial views, topographical maps, and building exteriors. In some countries, the process for designating an area for use as a cable landing site involves a regulatory or other governmental approval process that is in part open to the public.

Approximately 1,000 cable landing sites can be found on the Internet. The information provided for these sites includes the cable system termination at the site, the equipment supplier of the system, the date of deployment, and the cable route length.

B.7 Cable Routes

Substantial information is available to the public on the routes of undersea communications cable systems. Details include origination and termination points, segment end points, and paths. In addition, information is provided by the installers of new systems on the updates of progress being made and schedules. In some areas, cable route information is provided for use by the fishing industry. The data available include:

- Name of cable system (at segment level)
- Geographic region of location
- Date deployed
- Route length in kilometers
- Equipment suppliers providing component to build the system

In addition, detailed maps of cable systems can be found in the public domain. Images include:

- Global view of cable routes
- Landing points
- New reports of damaged cable locations
- Awareness maps for navigators

B.8 Outages

Long haul undersea communications cable systems are designed to perform at a level described as ultra-high reliability. However, despite all of the best planning and execution, failures of these systems still occur. The systems are also designed to be fault tolerant, meaning that a failure can be detected and dealt with gracefully such that there is minimal impact to the traffic being carried. This is often accomplished by the use of the system's spare capacity available in its paired redundant path. Increasingly, undersea cable systems are also rerouting their traffic to other systems – either undersea or land-based.

As the frequency, duration and cause of network failures is potentially sensitive information, it is understandable that much of this information is not available to the public. The information may be sensitive for reasons related to direct competitive business interests (i.e. comparison among systems), stakeholder subscriber interests (i.e. a carrier leasing space may be represented as having sub-optimum performance through association), or nation-state security.

However, outages that have a major impact tend to be reported in public news outlets. A detailed analysis of information publicly available on the Internet supported the following observations:

- on the order of 100 outages can be identified for the period from 2000 through 2009
- the outage locations are distributed across the globe
- outage events were found in each of the 12 months
- outage durations range from several hours to several months
- the primary causes (from the 8i Framework) of the events are associated with
    - Environment
    - Hardware
    - Power

In addition, there are suggestions that some events could have been caused by malicious activity, thus potentially involving the Human ingredient.

B.9 Restoration Procedures

Because system outages result in complete or partial service impairment, noncompliance with contracted service level agreement obligations, and expensive reroutes over alternate undersea or landline paths, the restoration of the system to its full functioning is urgent business. Outage detection, analysis and repair procedures are types of information available to the public.

Restoration of land-based equipment is obviously likely to be less involved. This type of restoration will most typically involve replacement of electronic hardware at the termination point or repair or replacement of power feed equipment. The restoration for buried or submerged equipment is more involved. When submerged equipment must be accessed, dedicated ships with specialized crew and equipment aboard are needed.

Given the vital dependence of undersea communications cable infrastructures on specialized cable ships, these vessels are appropriately considered a critical international asset. Public information on these ships is available and includes information such as:

- vessel name
- country of registration
- base port

- owner
- specific function regarding cable repair
- weight capacity
- photographs

B.10 Financial Dependencies

By and large, the undersea communications cable infrastructure is owned and operated by the private sector. A such, there are key business drivers throughout this process that motivate private sector stakeholders to make the investments, take the risks, and fund the research that has created the infrastructure we have today. For a complete perspective, we must take into account the financial factors affecting this industry. Below are some types of information available in the public domain regarding the financial impacts of GUCCI outages.

- The *cost* for a normalized (by distance and capacity) unit of undersea cable transmission has *dropped by 93%* from 1998 to 2008.[299]
- The number of people affected per country for specific undersea cable cuts.
- The cost per minute, hour or day for financial trading firms, call centers communications service providers, and other businesses.
- Estimates of the number of businesses that fail from specific undersea cable outages. [300]
- Specific details describing the amount of backlog created when three are outages (medical subscriptions, airline reservations, stock trades, orders, etc.).

[299] *Unit Cost of Submarine Cable Systems*, TeleGeography, 2008.
[300] National Archive & Records Administration.

APPENDIX C. Impact of Historic Outages

This section was prepared for the ROGUCCI Report by Michael Sechrist, fellow - U.S. Department of Homeland Security, graduate student - Harvard Kennedy School of Government, Cambridge, Massachusetts, and participant - ROGUCCI Global Summit.[301]

C.1 Recent Events

This section will briefly analyze recent cable breaks in Algeria 2003, Pakistan 2005, Taiwan 2006, Pakistan 2007, Vietnam 2007, Bangladesh 2007, Mediterranean 2008, Middle East 2008, West Africa 2009 and Taiwan again in 2009. The impact of these events on related societies is also discussed. The potential impact of a future multi-cable event is then analyzed.

CASE #1: Algeria 2003

EVENT: On May 21, 2003, a 6.8 magnitude earthquake affected the Bourmerdes region, outside the coast of Algeria.[302] The earthquake occurred 7 km offshore at a boundary between the European and Asian tectonic plates. As a tsunami 2 meters high traveled across the Mediterranean Sea, turbidity currents generated extensive submarine landslides.

DAMAGE: The earthquake killed 2,266, injured 10,261 and caused extensive structural damage to the city of Bourmerdes and elsewhere in the country. The undersea landslides generated from the earthquake cut undersea cables approximately "45 km offshore from the epicentral area and disturbed the communications link between Europe and several other countries in Asia and the Middle East."[303] Overall, undersea landslides damaged five communications cables.[304]

IMPACT: It took four cable ships six weeks to fix all the cables.[305] One repair involved replacing a 120 km section of cable. All things considered, the earthquake caused an estimated $100 million in damage.[306]

301 ORISE Acknowledgement: This research was performed under an appointment to the U.S. Department of Homeland Security (DHS) Scholarship and Fellowship Program, administered by the Oak Ridge Institute for Science and Education (ORISE) through an interagency agreement between the U.S. Department of Energy (DOE) and DHS. ORISE is managed by Oak Ridge Associated Universities (ORAU) under DOE contract number DE-AC05-06OR23100. All opinions expressed in this paper are the author's and do not necessarily reflect the policies and views of DHS, DOE, or ORAU/ORISE.

302 A. Ayadi, et. al., "Strong Algerian Earthquake Strikes Near Capital City," Eos, Vol. 84, No. 50, 16 December 2003. Accessed at http://atlas.cc.itu.edu.tr/~cakirz/papers/ayadi_etal_2003_EOS.pdf

303 Ibid.

304 ICPC, "Critical Infrastructure: Submarine Telecommunication Cables," Accessed at www.iscpc.org/publications/Critical_Infastructure_2009_V2.pps

305 Ibid.

306 Ibid.

CASE #2: Pakistan 2005

EVENT: On June 27, 2005, the only undersea communications cable connecting Pakistan with the rest of the world was disrupted. According to the repair company, the possible cause "was the fishing activity around the affected area," and "that an anchor of a fishing trawler had got entangled which ruptured the cable."[307] The disruption occurred 11-12 km from the port of Karachi.

DAMAGE: The breaks were significant. At the time, "Pakistan was the only country in the region that relies on a single cable. There were no backup cable, no disaster recovery strategy and no business continuity plan in place."[308]

Despite this plan, business suffered from the lost connection. As one airline director noted, "all our business including reservations, ticketing, check-ins and 500 agents all around the world are web-based and it was all affected badly. We had to switch to manual work and that was very difficult for us. Besides, we suffered severe damage to our market credibility."[309]

IMPACT: It took two cable repair ships over eleven days to fix the fault. According to an official from the Pakistani Internet service providers union, 10 million online subscribers in Pakistan went without Internet service for more than a week because of the fault.[310] All e-services were affected, particularly the burgeoning Pakistani call center industry. As the President of the Call Centres Association of Pakistan stated, "It has definitely caused millions of dollars in potential losses and a lot of intangible damage you cannot quantify."[311]

The loss of communications in a country of size and scope of Pakistan reverberated with its trading partners. Several multinational information and communication technology contracts were cancelled, most notably a $10-$20 million investment by Indian call centers. The Indian companies "withdrew the offer as the lingering Internet blackout caused mistrust in India about Pakistan's Telecom infrastructure."[312] India could not outsource their work to Pakistan, fearing that their U.S.-based contracts would be unfulfilled.

RECOVERY: During that outage, 50% of Internet subscribers and 20% of international phone callers received a connection via a back-up satellite plan provided by the Pakistani Communications Cable Limited company. The PTCL implemented an ad-hoc tiered restoration structure, providing data access first to banks, airlines and the Pakistani stock exchange access first before all others.

CASE #3: Taiwan 2006

EVENT: On December 26, 2006, a seminal event occurred in the undersea cable industry. An earthquake of at least 6.7 magnitude triggered a submarine landslide near the junction of the Eurasian and Philippine tectonic plates. Termed the Hengchun earthquake, the epicenter of the event landed directly in

[307] "Submarine cable: IT ministry preparing load-sharing plan," Pak Tribune, February 14, 2006. Accessed at http://www.paktribune.com/news/index.shtml?134126
[308] Hayyan Faisal, "Task to detect major Fault in Pakistan's Internet cable Set Off," *Pakistan Times*, July 2005. Accessed at http://pakistantimes.net/2005/07/04/top1.htm
[309] "Bad weather obstructs Pakistan's Fiber Optic cable repair Work" *Pakistan Times Staff Report,* July 5, 2005. Accessed at http://pakistantimes.net/2005/07/05/top6.htm
[310] Faisal, Pakistan Times.
[311] Ibid.
[312] Omair Rasheed, "Standby Net arrangements terminated in Pakistan," *Pakistan Times,* July 6, 2005. Accessed at http://pakistantimes.net/2005/07/06/top5.htm

the middle of the heavily cabled Luzon Strait, off the coast of Taiwan. Ten aftershocks greater than 4.7 magnitude also hit the region.[313] From the timing of the breaks, a turbidity current averaging a speed of approximately 20 km/hour traveled over 330 km.[314]

DAMAGE: Undersea landslides severed nine out of eleven cables in the area, moving cables far away from their original routes. A total of twenty-one faults were discovered in the nine damaged cable systems.[315] The damage extended to water depths of 4000 meters and covered many in tons of mud.[316] It took eleven cable ships (over 40% of the world's entire fleet) until February 15th – a total of forty-nine days or seven weeks to complete the cable repair work.[317]

IMPACT: The day after the earthquake, most people in Hong Kong were "just twiddling their thumbs."[318] Taiwan's international calling capacity to the U.S. was down to 40% its normal capacity.[319] 98% of Taiwan's communications with Malaysia, Singapore, Thailand and Hong Kong was also disrupted.[320] Internet access to China, Hong Kong, Vietnam, Taiwan, Singapore, Japan and the Philippines was seriously impaired. Banking, airline bookings, email & other services in many of these countries, particularly Taiwan and Singapore, were either stopped or delayed.[321]

Financial markets and general commerce were disrupted. A South Korean domestic bank reported that "trading of the Korean won has mostly halted due to the communication problem."[322] Other "securities traders in Hong Kong and Singapore were unable to obtain prices and complete orders… [and] dealers in the region said they have had difficulties accessing international news providers for information."[323] Customers also had trouble looking up various "stock prices online."[324]

RECOVERY: Some traffic that couldn't be carried on the two remaining undersea cable systems needed to find a different route in order to reach North and South America. One solution was to re-route traffic over terrestrial cables across Asia and through Europe. Despite these ad-hoc arrangements, some delay in internet traffic was still apparent even two months after the earthquake.

AFTERMATH: This event forced communications carriers to avoid cable-laying in seismically active areas when possible.

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313 2006 Hengchun earthquake, Wikipedia entry, accessed at http://en.wikipedia.org/wiki/2006_Hengchun_earthquake
314 ICPC, "Critical Infrastructure: Submarine Telecommunication Cables," Accessed at www.iscpc.org/publications/Critical_Infastructure_2009_V2.pps

315 Ryan Singel, "Fiber Optic Cable Cuts Isolate Millions From Internet, Future Cuts Likely," *Wired Magazine*, January 31, 2008. Accessed at http://www.wired.com/threatlevel/2008/01/fiber-optic
316 Ibid.
317 Ibid.
318 Seth Mydans, "The Day the Pixels Froze: When a Digital World Was Stopped by a Natural Disaster," *The New York Times*, December 28, 2006. Accessed at http://www.nytimes.com/2006/12/28/business/28connect.html
319 Sumner Lemon, "Earthquake disrupts Internet access in Asia," *Computer World Magazine*, December 27, 2006. Accessed at http://www.computerworld.com/s/article/9006819/Earthquake_disrupts_Internet_access_in_Asia?intsrc=news_ts_head
320 Ibid.
321 "Taiwan quake causes net blackout," *Reuters*. December 28, 2006. Accessed at http://www.smh.com.au/news/wireless--broadband/taiwan-quake-causes-net-blackout/2006/12/28/1166895395104.html
322 "Asia communications hit by quake," *BBC News,* December 27, 2006. Accessed at http://news.bbc.co.uk/2/hi/asia-pacific/6211451.stm
323 Choe Sang-Hun and Wayne Arnold, "Asian Quake Disrupts Data Traffic," *The New York Times*, December 28, 2006. Accessed at http://www.nytimes.com/2006/12/28/business/worldbusiness/28quake.html?pagewanted=all
324 Ibid.

CASE #4: Bangladesh 2007

Since connecting its first international undersea communications cable on May 21, 2006, Bangladesh has suffered numerous faults. In little over a year, twenty-two different faults were reported, either due to accidents, sabotage or thefts.

EVENTS: In November 2007, the Dhaka-Chittagong–Cox's Bazar portion of a submarine cable "was snapped at two points near Cox's Bazar and Feni" twice in one week.[325]

DAMAGE: All international communications to Bangladesh were disrupted for fifteen hours during the second outage.

IMPACT: Due to the cuts, the Bangladesh Telegraph and Telephone Board lost revenue on the order of $70,000 per hour.[326]

CASE #5: Middle East 2008

EVENT: Between January 23 and February 4, 2008, "a total of five cables being operated by two submarine cable operators" were damaged in two locations each.[327] A cable system segment that connected South East Asia-Middle East-Western Europe near Penang, Malaysia, another cable system that connected Europe-Asia near Alexandria, a cable system that connected Dubai, a cable system that served Bandar Abbas in Iran and a cable system that served Alexandria, were all disrupted. Reports would describe two ships, the MV Hounslow and the MT Ann, as having improperly dragged their anchors five miles north of Alexandria, Egypt, severing multiple cables.[328]

DAMAGE: The anchors "severed the cables outside Alexandria after bad weather conditions forced ships to moor off the coast."[329] Two of the cut cables "have a capacity close to 620 gigabits per second,"[330] leaving only one cable connecting Europe with Egypt and the Middle East in operation. The sole remaining cable "has a capacity of 70 gigabits per second," and could not handle the large influx in traffic.[331]

IMPACT: The cuts "affected at least 60 million users in India, 12 million in Pakistan, 6 million in Egypt and 4.7 million in Saudi Arabia."[332]

In Egypt and Pakistan, "70 percent of its connection to the outside Internet and 30 percent of service to its call-center industry, which depended less on the lines," were lost.[333] Also, "50 and 60 percent of India's Net outbound connectivity was similarly lost on the westbound route critical to the nation's burgeoning

[325] Sayeed Rahmna, "Bangladesh Submarine Cable link sabotaged again," Groundreport.com, November 13, 2007. Accessed at http://www.groundreport.com/Media_and_Tech/Bangladesh-Submarine-cable-link-sabotaged-again/2837950

[326] Ibid.
[327] Asma Ali Zain, "Cable damage hits 1.7m Internet users in UAE," *Khaleej Times*, February 5, 2008. Accessed at http://www.khaleejtimes.com/DisplayArticle.asp?xfile=data/theuae/2008/February/theuae_February155.xml&section=theuae
[328] Lewis Page, "Dubai impounds cable slicing ships: Satellite images used to ID Gulf cable miscreants," *The Register (UK)*, April 14, 2008. Accessed at http://www.theregister.co.uk/2008/04/14/undersea_cable_cut_ships_nabbed/
[329] Malcolm Fried and Lars Klemming, "Severed Cables in Mediterranean Disrupt Communication (Update4)," *Bloomberg.com*, December 19, 2008. Accessed at http://www.bloomberg.com/apps/news?pid=20601085&sid=aBa0lTN.dcoQ
[330] John Borland, **"**Analyzing the Internet Collapse: Multiple fiber cuts to undersea cables show the fragility of the Internet at its choke points," *Technology Review (MIT)*, February 5, 2008. Accessed at http://www.technologyreview.com/web/20152/?a=f
[331] Ibid.
[332] Ali Zain, *Khaleej Times*, 2008.
[333] Borland, *Technology Review*, 2008.

outsourcing industry."[334] Between those three countries, 2,500 networks went down during the outage period.

CASE #6: Mediterranean 2008

EVENT: Ten months later, it happened again. On December 19, 2008, three cable systems in the region "carrying more than 75% of traffic between the Middle East, Europe and America were damaged."[335] The cables run from Alexandria in northern Egypt to Sicily in southern Italy, connecting the Middle East and South Asia with Europe. The cuts were caused along the Italy to Egypt route and a ship anchor or bad weather was likely to blame.

IMPACT: At one point as much as 55% of voice traffic in Saudi Arabia, 52% in Egypt and 82% in India was out of service, according to Orange.[336]

Again, these cuts caused massive outages; one article reported these significant outages:[337] Saudi Arabia: 55% out of service; Djibouti: 71% out of service; Egypt: 52% out of service; United Arab Emirates: 68% out of service; India: 82% out of service; Lebanon: 16% out of service; Malaysia: 42% out of service; Maldives: 100% out of service; Pakistan: 51% out of service; Qatar: 73% out of service; Syria: 36% out of service; Taiwan: 39% out of service; Yemen: 38% out of service; Zambia: 62% out of service.

CASE #7: U.S. (California) 2009

EVENT: On April 4, 2009: "a total of ten fiber optic cables…were deliberately cut in three different locations in Southern California" within two hours.[338] One article notes that "a few vandals, equipped with pliers...cut fiber-optic cables in the San Francisco Bay area, paralyzing wireless, Internet, phone, and emergency communications for more than twelve hours."[339] The operation was easy; "whoever cut the fibers simply lifted the manhole cover, went down the ladder, and cut two cables."[340]

IMPACT: 1.5 million services were interrupted, including all ATM and credit card processing; 52,000 Verizon landlines lost service.[341] Although the case deals with a terrestrial cut, the situation makes the point that such a cut can happen on land.

CASE #8: West Africa 2009

EVENT: On July 30, 2009, the only cable connecting West Africa to other continents was severed.

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334 Ibid.
335 Eric Krangel, "Egypt Goes Dark: Mediterranean Data Cables Toast," *Business Insider.com*, December 19, 2008. Accessed at http://www.businessinsider.com/2008/12/egypt-goes-dark-mediterranean-data-cables-toast

336 Ibid.
337 Arsalan Tariq Mir, "Three Undersea Cables Slashed," *AMMAR-3SIXTY! Blog*, Accessed at http://ammar360.com/2008/12/20/three-major-undersea-cables-slashed/
338 Kevin Burton, Angela McGee, Jack Dibeler, "Who Turned Out the Light?" Burton Asset Management, 2009. Accessed at http://www.thinkbam.com/thinking/WebArticles/WhoTurnedOutTheLight.pdf
339 Ibid.
340 Margeurite Reardon, "How secure is the U.S. communications network?," *CNet News*, April 13, 2009. Accessed at http://news.cnet.com/8301-1035_3-10217550-94.html?part=rss&subj=news&tag=2547-1_3-0-20
341 Burton, et al., Burton Asset Management report, 2009.

IMPACT: Internet traffic was significantly disrupted to Benin, Togo, Niger and Nigeria. Nigeria appeared to be worst hit, as close to "70% of Nigeria's bandwidth was cut, causing severe problems for its banking sector, government and mobile phone networks."[342]

CASE #9: Taiwan 2009

EVENT: On August 12, 2009, Typhoon Morakot, which triggered massive flooding in Taiwan, knocked out multiple cable systems in the area.[343] A week after the Typhoon, a 6.5 magnitude earthquake struck the region.[344] According to Verizon, "10 submarine cable systems in the Asia-Pacific region were damaged in more than 20 locations."[345]

IMPACT: Qatar and Singapore suffered the greatest communications failures. In addition, cable operators in Indonesia, the Philippines, South Korea and Japan all suffered disruptions to their networks.[346]

C.2 RECENT CABLE THEFTS

Acts of theft and sabotage are not new. The Vietnam case in 2007 can be considered both theft and sabotage as it was designed to earn a profit by severing optical cable systems.

CASE #1: Vietnam 2007

In March 2007, a large undersea cable disruption in Vietnam occurred due to man-made activity, not natural disasters. In August 2006, the Vietnamese province of Ba Ria-Vung contracted "several companies to salvage undersea copper cable left over by the former government of South Vietnam..."[347]

Instead of recovering old cable, the companies and other fisherman started to pull up new ones. In the end, over 500km of cables was recovered from five illegal cable ring networks, with "roughly 43 km of fiber optic cable…belonging to a company in Singapore."[348]

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[342] "Cable fault cuts off West Africa," *BBC News*, July 30, 2009. Accessed at http://news.bbc.co.uk/2/hi/technology

[343] Victoria Ho, "Typhoon knocks out Asia telecom cable," *CNet News*, August 13, 2009. Accessed at http://news.cnet.com/8301-1035_3-10308348-94.html

[344] *Robert Clark, "*After the typhoon, quake slows net access to a crawl," *Telecomasia.net*, August 19, 2009. Accessed at http://www.telecomasia.net/content/after-typhoon-quake-slows-net-access-crawl

[345] Verizon Business press release, "Verizon Business Global Mesh Network Investment Pays Big Dividends for Enterprise Customers During Multiple Submarine Cable System Disruptions in Asia-Pacific Region; All Restorable Customer Traffic Moved to New Routes Within Milliseconds," *M2 Newswire.com*, September 18, 2009. Accessed at http://www.highbeam.com/doc/1G1-208059844.html

[346] Ek Heng, "Typhoon Morakot damages several subsea cable systems," *Telecomengine.com*, August 19, 2009. Accessed at http://www.telecomengine.com/article.asp?HH_ID=AR_5575

[347] Matt Steinglass, "Undersea Cable Thieves Slow Vietnam's Internet Access," *VOA News.com*, June 1, 2007. Accessed at http://www1.voanews.com/english/news/a-13-2007-06-01-voa14-66777382.html

[348] *Jacqui Cheng, "Phishing plumbs new depths: Vietnamese fishermen sever fiber optic lines,"* Arstechnica.com*, June 8, 2007. Accessed at http://arstechnica.com/old/content/2007/06/phishing-plumbs-new-depths-vietnamese-fishermen-sever-fiber-optic-lines.ars*

The cable thefts forced Vietnam to rely on one submarine cable for 82% of voice and data traffic.[349] Other traffic was pushed to terrestrial lines and satellite, creating Internet delays for up to three months after the thefts.[350] To replace an eleven km section, Vietnam paid $5.8 million. More than the money, Vietnam's credibility suffered as it sought to restore itself with the rest of the world.[351] The Prime Minister of Vietnam said the theft "directly affects Vietnam's socio-economic development, national security and the country's prestige in the region as well as in the world."[352]

So far, press reports of criminal prosecutions are available, but no official report has been published. Claims for compensation remain ongoing. The Prime Minister embarked on a campaign to educate the public on the significance of submarine cables so as to avoid anymore unwarranted cable theft.

CASE #2: Jamaica 2008

In Jamaica, "theft of copper cable was reported to have reached epidemic proportions, costing one company over J$100m ($1.2 million) in losses and forcing them to offer J$1m ($12,000) for information leading to the arrest of the cable thieves."[353] The problem was out of control with reports stating thieves were stealing cable "at one end of a route while it was being replaced at the other."[354]

CASE #3: South Africa

One South African cable company "recently reported losses due to copper cable theft totaling almost 1bn rand – over [$100 million] – each year."[355]

C.3 Potential Impact

In many of the cases, an undersea cable disruption caused severe problems to one or more countries. Corporations lost millions, militaries lost missions, publics lost connections, and countries lost national prestige. Since major banks can operate in upwards of 100 countries around the world, large multi-national corporations are increasingly vulnerable to outages around the world. The problem has become less localized and more globalized than it ever has been.

It is clear that undersea fiber-optic communications cables profoundly impact in the age of information. For instance, nearly all international data and communications flow over undersea cables. The vast majority of U.S. government international data traffic, at least at the unclassified level, is sent on commercially owned and operated undersea cables. This situation is similar in almost all countries.

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[349] "Critical Infrastructure: Submarine Telecommunication Cables," ICPC, Accessed at www.iscpc.org/publications/Critical_Infastructure_2009_V2.pps
[350] Ibid.
[351] See Burnett, Douglas R. and Mick P. Green. "Security of International Submarine Cable Infrastructure: Time to Rethink?." *Legal Challenges in Maritime Security*. Eds. Ronán Long, John Norton Moore, Myron H. Nordquist and Rüdiger Wolfrum. Martinus Nijhoff Publishers, 2008.
[352] Ibid.
[353] Cathy Holding, "A global cable network of fragile links," *The Independent (UK), March 10, 2009. Accessed at* http://www.independent.co.uk/news/business/sustainit/a-global-cable-network-of-fragile-links-1640448.html
[354] Ibid.
[355] Ibid.

The profound importance of cables is also noted in regards to international commerce. The Chief of Staff for the Chairman of the U.S. Federal Reserve recently stated that "when communications networks go down, the financial services sector does not grind to a halt, rather it snaps to a halt."[356] Based on the sheer numbers, it is easy to see why this is true. The Society for Worldwide Interbank Financial Telecommunication (SWIFT), which describes itself as "the global provider of secure financial messaging services,"[357] uses undersea fiber-optic communications cables to transmit financial data between 208 countries. In 2004 alone, 9 million messages and approximately $7.4 trillion a day were traded on this network.[358] Today, nearly 15 million messages a day are sent over it. The CLS Bank, which "operates the largest multi-currency cash settlement system," trades over 1 million transactions and over $4.7 trillion dollars a day over the same undersea cables.[359] With trillions traded daily, a multi-cable outage, especially in a regional financial hub, like Taiwan/China/Hong Kong, has enormous ramifications on the trust and soundness of the global financial order.

Moreover, in the 2006 Hengchun earthquake case, it took ships seven weeks to repair all disrupted cables. When millisecond delays can lose millions in real-time trading companies, seven weeks is an eternity. Without a fool-proof back-up plan, communications carriers and end-users can jeopardize profit and investor confidence. Even with a sound back-up plan, the cost differential in service restoration can be huge. In the case of Taiwan 2006, the cost of going over land was thirty times the cost of going over water in the back-up plan.[360] Additional latency is typically another problem companies' face in these situations too. Satellite back-up is usually not a feasible option.

Secondary effects with cable outages are also significant. A simulation in an advanced industrial country proved just how important cables are to ancillary industries. The official involved in the simulation noted that his government soon realized that if one or more cables went down, air traffic controllers "wouldn't be able to land planes because you couldn't check who is on them."[361] In the global age of terrorism, planes can land only after all passengers are background checked. This example is one of many proving that cable outages have large first, second and third-order effects that can reverberate within a country, within a region and within the international community. Governments and companies worldwide need to do much more to protect against a future multi-cable disruption in order to avoid such effects.

[356] Stephen Malphrus, "Keynote Address," ROGUCCI Summit, Dubai, U.A.E., October 19, 2009.
[357] Ibid.
[358] Ibid.

[359] Ibid.
[360] Mick Green, ICPC Presentation to the ROGUCCI Summit, October 19, 2009.
[361] Comments made by Australian official to ROGUCCI Summit members, October 22, 2009.

APPENDIX D. Financial Stability Board Core Standards

Table 12. 12 Core Standards of the Financial Sector[362]

12 Core Standards
Macroeconomic Policy and Data Transparency
Monetary and financial policy transparency
Fiscal policy transparency
Data dissemination
Institutional and Market Infrastructure
Insolvency
Corporate governance
Accounting
Auditing
Payment and settlement
Market integrity
Financial Regulation and Supervision
Banking supervision
Securities regulation
Insurance supervision

[362] Financial Stability Board, *12 Key Standards for Sound Financial Systems*, www.financialstabilityboard.org/cos/key_standards

APPENDIX E. Cable-Cutting in War Time – Reference

The Pall Mall Gazette, May 11, 1898

From The Pall Mall Gazette.

Unquestionably people's minds are directed very much just now to the question of the ability of this country to maintain telegraphic communication with the outer world, more particularly, of course, with her colonies, in times of war. Of course such speculations owe their origin to the war which, up to the moment, is being waged between America and Spain. Somewhat alarming pictures have been painted of England's isolation in times of a European upheaval, cut off from her kinsmen beyond the seas. Are they justified, and what is their application to the present war?

To settle questions of this character a representative of The Pall Mall Gazette made the journey to-day to West Cromwell Road to see Mr. Charles Bright, F. R. S. E., than whom no one knows more of cable questions. Mr. Bright's father, Sir C. Bright, as a matter of fact, laid all the cables connecting the United States and the West Indian Islands—some 4,000 miles—about the year 1870. And Mr. Bright has himself been engaged in the subsequent repair of one of these lines. These are, of course, immensely important cables just now.

Mr. Bright, when his visitor had opened the conversation, said he had little doubt that cables would be cut right and left in time of war, and this notwithstanding the idea which some seem to cherish that cables would be as safe in time of war as in time of peace. Of course it was not so. That was shown by a particular clause in the international convention, which did not attempt to bind the hand of either belligerent in the matter of cutting cables during a war.

"Why," said Mr. Bright, "it is known for certain that some years ago, when there was a prospect of war, the Russians had a ship fitted up with special apparatus for picking up cables

"But it is not necessary to have a cable ship in order to do damage to a cable. It is the easiest thing in the world—an innocent-looking bonfire on shore will do it, before, perhaps, there is any suggestion of war. The reason is that the cables are ended in lonely out-of-the-way places. The cable hut, which is built for testing direct from the cable, and from which a land line proceeds to the town where the signaling is done, is visited at the outside once a week as a rule. How easy for a fisherman, say, properly bribed, to light a fire on the beach where the cables are and break the circuit.

"The argument of some people that, because our cables, say in the Mediterranean, are laid in our principal trade routes, where men-of-war are to protect them, they could not be got at by the enemy is not entirely convincing."

Mr. Bright proceeded from this to argue with great cogency the need that exists for an all-British cable. He pointed out, by means of a map which he has drawn up, that the route suggested from Vancouver Island, through the Fiji, to Norfolk Island, and thence to New Zealand and Australia, possesses many advantages, notably because it lay in the deep Pacific, because its ends could be easily defended, and because it was comparatively inaccessible to those who would be likely to try to injure it in time of war. Russia, for instance, we were reminded, would find great difficulty in cutting up a cable in the Pacific.

The American route across the North Pacific, starting from San Francisco, through the Sandwich Islands to Japan, also commended itself to Mr. Bright as being a highly useful scheme, provided an extension were made to Australia.

Mr. Bright pointed out that an alliance with America and Japan would give us almost the security we desired for continuous cable communication in time of war.

With every desire to be absolutely impartial, Mr. Bright commented on the usefulness of the Eastern Telegraph Company's scheme of a cable via Gibraltar and the Cape to Australia, but pointed out that the great defect was that Canada, who had ever been foremost in desiring cable communication with Australia and the rest of the British Empire, was completely shut off. Moreover, though uniting certain important naval stations, it might not meet the want, from a strategic point of view, so effectually.

With regard to the all-British Pacific route, our expert mentioned that while it gave what the colonies so ardently desired, direct communication, and though introducing no serious engineering difficulties, yet it was clear to any electrician that it would be costly in construction, and by reason of the great lengths between the land points, would be made more difficult to repair.

But, said Mr. Bright, an extra and independent string to our bow is obviously an advantage; and by laying a cable on this entirely new route we should no longer be guilty of putting all our telegraphic eggs into one oceanic basket, though it was but human of shareholders in existing systems to look at things differently.

There was another important point touched upon in the conversation. It was thus expressed by Mr. Bright: "No doubt great care should be taken to only let certain people know the position of these cables. Of course, the shore ends must be shown to prevent ships from anchoring on the cable, but there would be no particular harm in giving this information, and in an all-British cable the various landing places could be defended by soldiers."

In his subsequent remarks Mr. Bright insisted on the correctness of his view from an imperial standpoint—the sovereign necessity of binding together, electrically, all parts of the empire, and of furthering imperial free trade, which would render us independent of the good offices of the rest of the world. "Such a consummation," said Mr. Bright, with the energy of an enthusiast, "is furthered more than anything else by connecting up the mother country with the colonies."

Dealing more directly with the American and Spanish war, Mr. Bright was inclined to ridicule the idea that the Americans would cut the cable from Key West to Havana. By this process they would cut themselves off from their fleet.

Mr. Charles Bright is publishing a book (through Messrs. Crosby Lockwood and Sons) in a few days, entitled "Submarine Telegraphs." It contains a full account of these West Indian cables, besides dealing at length with what may be termed the politics of the world's electric nerves.

APPENDIX F. United Nations Convention on the Law of the Seas (UNCLOS) – Highlights

The United Nations Convention on the Law of the Seas (UNCLOS) provides special status for undersea communications cables, including special provisions for their protection.[363]

Article 21. Laws and regulations of the coastal State relating to innocent passage:

1. The coastal State may adopt laws and regulations, in conformity with the provisions of this Convention and other rules of international law, relating to innocent passage through the territorial sea, in respect of all or any of the following: . . . (c) the protection of cables and pipelines;

Article 58. Rights and duties of other States in the exclusive economic zone

1. In the exclusive economic zone, all States, whether coastal or land-locked, enjoy, subject to the relevant provisions of this Convention, the freedoms referred to in article 87 of navigation and over flight and of the laying of submarine cables and pipelines, and other internationally lawful uses of the sea related to these freedoms, such as those associated with the operation of ships, aircraft and submarine cables and pipelines, and compatible with the other provisions;

Article 79. Submarine cables and pipelines on the continental shelf

1. All States are entitled to lay submarine cables and pipelines on the continental shelf, in accordance with the provisions of this article.
2. Subject to its right to take reasonable measures for the exploration of the continental shelf, the exploitation of its natural resources and the prevention, reduction and control of pollution from pipelines, the coastal State may not impede the laying or maintenance of such cables or pipelines.
3. The delineation of the course for the laying of such pipelines on the continental shelf is subject to the consent of the coastal State.
4. Nothing in this Part affects the right of the coastal State to establish conditions for cables or pipelines entering its territory or territorial sea, or its jurisdiction over cables and pipelines constructed or used in connection with the exploration of its continental shelf or exploitation of its resources or the operations of artificial islands, installations and structures under its jurisdiction.
5. When laying submarine cables or pipelines, States shall have due regard to cables or pipelines already in position. In particular, possibilities of repairing existing cables or pipelines shall not be prejudiced.

Article 87. Freedom of the high seas

1. The high seas are open to all States, whether coastal or land-locked. Freedom of the high seas is exercised under the conditions laid down by this Convention and by other rules of international law. It comprises, *inter alia*, both for coastal and land-locked States:
(a) freedom of navigation;
(b) freedom of over flight;
(c) freedom to lay submarine cables and pipelines, subject to Part VI;
(d) freedom to construct artificial islands and other installations permitted under international law, subject to Part VI;
(e) freedom of fishing, subject to the conditions laid down in section 2;
(f) freedom of scientific research, subject to Parts VI and XIII.
2. These freedoms shall be exercised by all States with due regard for the interests of other States in their exercise of the freedom of the high seas, and also with due regard for the rights under this Convention

[363] October, 1982, www.un.org/Depts/los/convention_agreements/convention_overview_convention.htm.

with respect to activities in the Area.

Article 112. Right to lay submarine cables and pipelines

1. All States are entitled to lay submarine cables and pipelines on the bed of the high seas beyond the continental shelf.
2. Article 79, paragraph 5, applies to such cables and pipelines.

Article 113. Breaking or injury of a submarine cable or pipeline

Every State shall adopt the laws and regulations necessary to provide that the breaking or injury by a ship flying its flag or by a person subject to its jurisdiction of a submarine cable beneath the high seas done wilfully or through culpable negligence, in such a manner as to be liable to interrupt or obstruct telegraphic or telephonic communications, and similarly the breaking or injury of a submarine pipeline or high-voltage power cable, shall be a punishable offence. This provision shall apply also to conduct calculated or likely to result in such breaking or injury. However, it shall not apply to any break or injury caused by persons who acted merely with the legitimate object of saving their lives or their ships, after having taken all necessary precautions to avoid such break or injury.

Article 114. Breaking or injury by owners of a submarine cable or pipeline of another submarine cable or pipeline

Every State shall adopt the laws and regulations necessary to provide that, if persons subject to its jurisdiction who are the owners of a submarine cable or pipeline beneath the high seas, in laying of repairing that cable or pipeline, cause a break in or injury to another cable or pipeline, they shall bear the cost of the repairs.

Article 115. Indemnity for loss incurred in avoiding injury to a submarine cable or pipeline

Every State shall adopt the laws and regulations necessary to ensure that the owners of ships who can prove that they have sacrificed an anchor, a net or any other fishing gear, in order to avoid injuring a submarine cable or pipeline, shall be indemnified by the owner of the cable or pipeline, provided that the owner of the ship has taken all reasonable precautionary measures beforehand.

Article 297. Limitations on applicability of section 2

1. Disputes concerning the interpretation or application of this Convention with regard to the exercise by a coastal State of its sovereign rights or jurisdiction provided for in this Convention shall be subject to the procedures provided for in section 2 in the following cases:
(a) when it is alleged that a coastal State has acted in contravention of the provisions of this Convention in regard to the freedoms and rights of navigation, overflight or the laying of submarine cables and pipelines, or in regard to other internationally lawful uses of the sea specified in article 58;

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