A RedMars Initiative

The STAR Certification Framework

Spaceflight Training and Advanced Readiness (STAR)

A Competency-Based Certification Standard for the Spaceflight Workforce

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Framework Repository
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Contents

Abstract

The global space industry is undergoing rapid expansion driven by commercial launch providers, satellite constellations, private astronaut programs, and increasing international participation in space missions [1]. As this ecosystem grows, the need for a standardized framework to assess operational readiness and competency across the spaceflight workforce becomes increasingly important.

The Spaceflight Training and Advanced Readiness (STAR) Certification Framework introduces a competency-based professional certification system designed to validate the knowledge, operational skills, and mission readiness of personnel participating in spaceflight missions.

STAR defines a structured progression of certifications spanning foundational spaceflight knowledge, spacecraft mission operations, vehicle operations, and human astronaut readiness.

By establishing clear competency standards and certification pathways, the STAR framework aims to improve mission safety, operational consistency, and workforce preparedness across the rapidly expanding spaceflight industry.

1 Summary

The Spaceflight Training and Advanced Readiness (STAR) Certification is a competency-based professional certification framework designed to establish standardized training and operational readiness for personnel involved in spaceflight missions.

As the global space industry expands, organizations increasingly rely on multidisciplinary teams responsible for spacecraft development, mission control operations, satellite management, launch coordination, and human spaceflight.

Despite this growth, there is currently no unified certification framework that validates operational competency across these roles in a standardized manner across the commercial space industry [2, 3].

The STAR certification addresses this gap by providing an industry-aligned standard that verifies an individual's readiness to safely and effectively participate in spaceflight missions.

The STAR framework is organized into four progressive certification levels:

- Level 1 – Spaceflight Foundations
- Level 2 – Mission Operations
- Level 3 – Vehicle Operations
- Level 4 – Astronaut Certification

STAR certifications are competency-based rather than training-based, meaning certification is granted upon successful demonstration of required knowledge and operational skills through examinations, simulations, and operational scenario evaluations.

2 Goal

The goal of the STAR Certification Framework is to establish a standardized competency-based system for assessing operational readiness across the growing spaceflight industry.

As spaceflight expands beyond government space agencies to include commercial launch providers, satellite operators, research institutions, and private astronaut programs, the need for consistent competency standards becomes increasingly important.

The STAR framework provides a structured certification pathway that validates the knowledge and operational readiness of individuals participating in spaceflight missions.

By defining standardized certification levels and pathways, the STAR framework aims to improve:

- Operational safety
- Workforce readiness
- Mission reliability

Over time, the STAR program intends to collaborate with established aerospace institutions to ensure that certification standards remain aligned with evolving industry practices [2, 4].

3 Industry Training Model

The STAR Certification Framework is designed to complement existing aerospace training programs by establishing a standardized, transferable baseline of operational competency across the spaceflight workforce.

Today, most commercial space organizations develop internal training programs for mission operators, spacecraft engineers, and astronaut candidates. While effective for specific missions and vehicles, this approach results in training that is often non-transferable across organizations and requires repeated development of similar foundational content.

The STAR framework introduces a model analogous to professional certification systems used in aviation and other technical domains, where foundational competencies are standardized independently of specific platforms or employers. Individuals may obtain STAR certifications prior to employment, demonstrating competency in spaceflight operations and spacecraft systems at a system-level.

Organizations may then focus internal training efforts on vehicle-specific, mission-specific, and proprietary procedures, rather than duplicating foundational operational instruction.

This approach is not intended to replace existing training programs, but to provide a common structure through which foundational competencies can be defined, assessed, and recognized across organizations.

This model enables:

- Reduced duplication of foundational training across organizations
- More efficient allocation of training resources toward mission-specific requirements
- A standardized and transferable competency baseline across the industry
- Increased workforce mobility between organizations
- Clear and structured career pathways for students and professionals entering the space sector

4 Positioning, Differentiation, and Scope

4.1 Relationship to Existing Training Initiatives

A number of existing programs, including commercial astronaut training providers, analog astronaut environments, and research-focused initiatives such as those offered by the International Institute for Astronautical Sciences, provide valuable experiential and mission-specific training capabilities.

Emerging industry trends indicate a growing need for scalable workforce development and standardized training approaches to support the expansion of commercial and government spaceflight operations.

However, these efforts primarily define training experiences, institutional models, or strategic direction, rather than a standardized certification architecture.

These programs are not in conflict with the proposed framework; rather, they represent critical inputs that can be structured and standardized within a broader certification architecture.

In this context, "inputs" refer to existing sources of education, training, and early-career experience, while "outputs" represent the organizations and operational environments that require a qualified, standardized spaceflight workforce.

Figure 1 illustrates the intended role of the STAR Certification Framework within the broader spaceflight training ecosystem.

As shown, the framework operates as an intermediary structure between training inputs and operational workforce outcomes, rather than as a standalone training provider.

This work differs in that it proposes a modular, system-level certification framework designed to enable:

- Transferable competencies across organizations, missions, and vehicle types
- Standardized evaluation of operational readiness and system-level proficiency
- Interoperability between government, commercial, and academic training pathways

Rather than replacing or competing with existing programs, this framework is intended to provide a unifying structure within which such programs may align and contribute to a broader certification ecosystem.

4.2 Training Paradigm and Value Proposition

Current spaceflight training is typically mission-specific, vehicle-dependent, and organization-defined, resulting in limited transferability of skills between programs.

The framework proposed in this work introduces a modular, systems-oriented training paradigm, where competencies are defined at the level of:

- Spacecraft subsystems

- Mission operations phases
- Cross-disciplinary functional roles

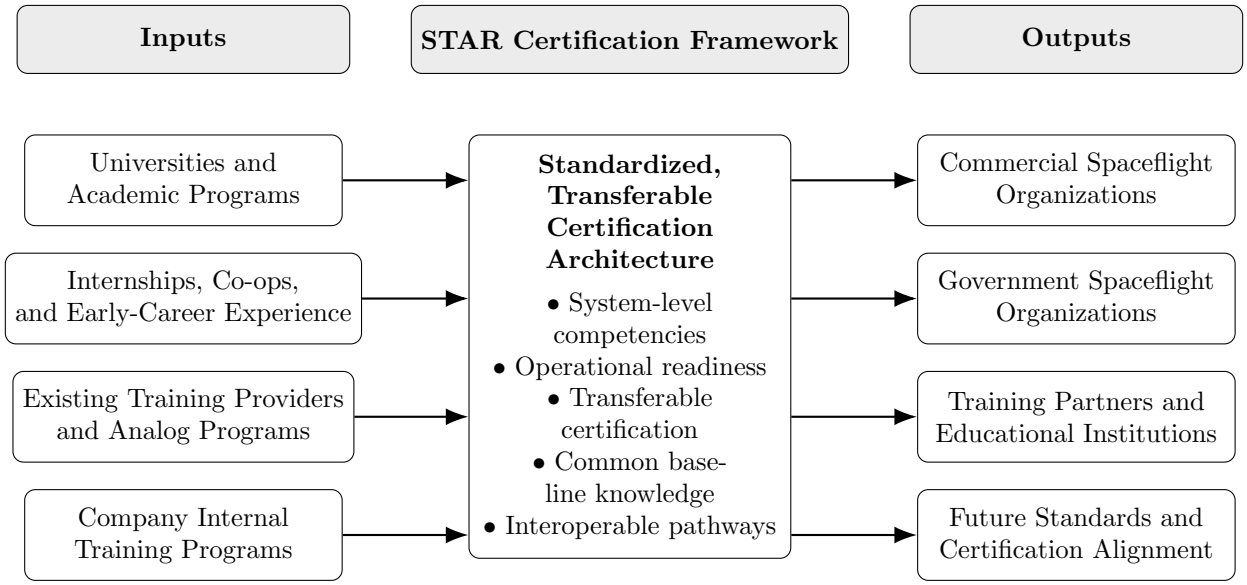

Figure 1: Conceptual positioning of the STAR Certification Framework within the broader spaceflight training ecosystem. The framework is intended to unify inputs from academia, experiential training, and employer-specific instruction into a transferable certification structure that supports workforce development across commercial, government, and educational spaceflight domains.

This approach enables the development of standardized competency definitions that are not tied to a single platform or mission profile.

The value proposition of this framework lies in its ability to:

- Support scalable workforce development across multiple organizations
- Reduce redundancy in training across similar system domains
- Enable personnel mobility within a growing commercial space ecosystem
- Provide a foundation for future certification and regulatory alignment

4.3 Bridging the Gap Between Academia and Industry

A persistent gap exists between academic preparation and operational readiness in the space industry.

Academic institutions provide strong theoretical and analytical foundations but often lack exposure to:

- Integrated spacecraft system interactions
- Real-time mission operations environments

- Cross-functional coordination between engineering, operations, and safety

Conversely, industry training programs provide practical experience but are often narrowly scoped to specific systems, missions, or proprietary architectures.

This framework addresses this gap by defining applied, system-level competencies that:

- Connect foundational academic knowledge to operational contexts
- Emphasize end-to-end mission understanding
- Promote cross-disciplinary systems thinking

The result is a structured pathway from education to operational proficiency, supporting both new entrants and transitioning professionals.

4.4 Scope and Non-Objectives

This work is not intended to:

- Serve as a space tourism or short-duration experiential training model
- Replace mission-specific astronaut training programs
- Establish a single training institution or proprietary program

Instead, the focus is on defining a professional certification structure applicable to sustained participation in spaceflight operations, including:

- Engineering roles
- Mission operations and flight control
- Systems integration and safety

The framework is designed to be implementation-agnostic, allowing adoption across diverse organizational and operational contexts.

4.5 Workforce Gaps and Target Competencies

While internships, cooperative education programs, and early-career roles provide valuable experience, they do not consistently develop the integrated competencies required for spaceflight operations.

Key gaps identified include:

- System-level understanding across spacecraft subsystems
- Familiarity with full mission lifecycle operations
- Ability to operate within cross-disciplinary teams

- Awareness of operational constraints in dynamic environments

This framework addresses these gaps by emphasizing:

- Holistic system comprehension
- Operational context and decision-making
- Cross-domain communication and coordination

4.6 Adoption and Implementation Considerations

Adoption of this framework is envisioned through a phased and collaborative approach, including:

- Pilot implementations within academic or training environments
- Integration into existing industry training pipelines
- Alignment with emerging standards bodies and regulatory frameworks

The framework is intentionally designed to be:

- Modular, allowing incremental adoption
- Adaptable, supporting organization-specific requirements
- Non-disruptive, complementing existing training systems

Over time, demonstrated utility and industry collaboration may support broader endorsement and standardization.

4.7 Target Stakeholders

The primary stakeholders for this framework include:

- Commercial spaceflight organizations
- Government agencies supporting human spaceflight
- Academic institutions preparing future spaceflight professionals

Secondary stakeholders include:

- Training providers and simulation developers
- Standards organizations and regulatory bodies

The framework is ultimately intended to support the development of a professional, certified spaceflight workforce, rather than a single program or institution.

5 Definition of the STAR Certification

The STAR Certification is a competency-based framework that validates an individual's knowledge, skills, and operational readiness to participate in spaceflight missions.

Unlike traditional educational credentials that primarily measure course completion, STAR certification verifies demonstrated capability.

Operational knowledge requirements for spacecraft missions are commonly derived from established aerospace engineering and mission operations practices [2, 3, 5].

Certification assessments may include:

- Written examinations
- Operational scenario evaluations
- Simulation-based mission exercises
- Practical demonstrations of spacecraft system operations

Certification may be obtained through two pathways:

5.1 Training Pathway

Candidates complete STAR-approved training programs prior to attempting certification assessments.

5.2 Challenge Pathway

Candidates with relevant education or industry experience may directly attempt certification assessments without completing STAR training courses.

6 Certification Levels

Figure 2: STAR Certification Framework (Levels and Typical Progression)

6.1 Level 1 – Spaceflight Foundations

Level 1 defines the baseline knowledge and foundational competencies associated with entry into the spaceflight ecosystem, consistent with common space mission training and engineering baselines [5].

Level 1 does not prescribe a specific training program or certifying authority. Instead, it defines a structured, competency-based foundation that may be implemented by academic institutions, training providers, or industry organizations.

CubeSat programs have become a common entry point for students and early-career engineers participating in space missions, providing practical exposure to spacecraft design, integration, and operations [6].

Representative foundational designations include:

- STAR-FND – Spaceflight Fundamentals
- STAR-SAFE – Space Safety
- STAR-ENV – Space Environment

This level is primarily applicable to individuals such as:

- University aerospace students
- CubeSat program members
- Early-career aerospace engineers

- Aerospace interns

These designations illustrate foundational competencies expected for entry-level participation in spaceflight-related roles, rather than defining a specific training or credentialing authority.

6.2 Level 2 – Mission Operations

Level 2 certifications represent competencies associated with spacecraft mission operations conducted from ground-based control environments.

Level 2 does not prescribe a specific training program or certifying authority. Instead, it defines a structured, competency-based framework for mission operations certification that may be implemented by government agencies, commercial operators, or accredited training organizations.

Spacecraft mission operations practices are influenced by telemetry and telecommand standards widely used across spacecraft communications architectures, including those defined by the Consultative Committee for Space Data Systems (CCSDS) [7].

Representative certification designations within Level 2 include:

- STAR Level 1 Certification
- STAR-MOS – Mission Operations
- STAR-GSO – Ground Systems Operations
- STAR-SSO – Small Satellite Operations

Example elective subsystem designations include:

- STAR-PWR – Power Systems
- STAR-COM – Communications Systems
- STAR-GNC – Guidance Navigation and Control
- STAR-CDH – Command and Data Handling
- STAR-THER – Thermal Control
- STAR-STRUC – Structures
- STAR-PLD – Payload Operations
- STAR-HSS – Human Spaceflight Systems

These designations illustrate how mission operations roles and subsystem competencies may be structured within a standardized certification framework, rather than defining a specific training or credentialing authority.

6.3 Level 3 – Vehicle Operations

Level 3 certifications represent competency in spacecraft vehicle operations and flight procedures, building upon operational principles and systems engineering foundations [2, 3].

Level 3 does not prescribe a specific training program or certifying authority. Instead, it defines a structured, competency-based framework for spacecraft operations certification that may be implemented by government agencies, commercial operators, or accredited training organizations.

Representative certification designations within Level 3 include:

- STAR Level 1 Certification
- STAR Level 2 Certification
- STAR-SCO – Spacecraft Operations Certification
- STAR-HSS – Human Spaceflight Systems

Future extensions of this framework may include vehicle-specific operational qualifications analogous to aircraft type ratings, enabling operators to demonstrate proficiency on specific spacecraft platforms within a standardized certification structure.

These designations are intended to illustrate how operational roles and competencies may be structured within a transferable certification framework, rather than to define a specific training or credentialing authority.

6.4 Level 4 – Astronaut Certification

Level 4 represents the highest certification level within the STAR framework and focuses on defining competency structures for human spaceflight operations.

Level 4 does not prescribe a standalone astronaut training program or certification authority. Instead, it defines a structured, competency-based framework for astronaut certification that may be implemented by qualified training organizations, government agencies, or commercial spaceflight providers.

Human spaceflight operational procedures and astronaut training methodologies are informed by established programs developed by government space agencies and aerospace organizations [8, 9].

6.4.1 Medical Certification Considerations

Human spaceflight operations require medical evaluation standards to assess crew fitness for flight. In the United States, medical certification for commercial spaceflight crewmembers is governed by the Federal Aviation Administration (FAA), including requirements defined under 14 CFR Part 67 and 14 CFR Part 460.

These medical certifications evaluate the risk of in-flight incapacitation based on an individual's medical history and operational role. Crewmembers participating in human spaceflight missions may be required to obtain appropriate medical certification prior to flight.

In addition to regulatory requirements, voluntary consensus standards for spaceflight participants have been developed through organizations such as ASTM International [10]. For example, ASTM F3180-20 defines voluntary standards for commercial spaceflight participants, including medical and training considerations [11].

While existing frameworks primarily address medical eligibility, the STAR framework is intended to complement these requirements by defining standardized, competency-based certification structures that may be used to support astronaut training, operational readiness, and mission execution.

Together, medical certification and operational certification represent complementary components of overall mission readiness.

The following represent example certification designations within the Level 4 framework structure::

- STAR Level 1 Certification
- STAR Level 2 Certification
- STAR Level 3 Certification
- STAR-ASC – Astronaut Candidate Certification
- STAR-AFS – Astronaut Flight Systems Certification

Example specialist designations include:

- STAR-EVA – Extravehicular Operations
- STAR-ROB – Space Robotics

Example advanced mission role designations include:

- STAR-MSA – Mission Specialist Astronaut Certification
- STAR-SCC – Spacecraft Commander Certification

These designations are intended to illustrate how astronaut roles and competencies may be structured within a standardized certification framework, rather than to define a specific training or credentialing authority.

6.5 Certification Designation Overview

Key certification designations include:

- STAR-FND – Spaceflight Fundamentals
- STAR-SAFE – Space Safety and Risk Awareness
- STAR-ENV – Space Environment
- STAR-MOS – Mission Operations Systems
- STAR-GSO – Ground Systems Operations
- STAR-SSO – Small Satellite Operations
- STAR-SCO – Spacecraft Operations
- STAR-ASC – Astronaut Candidate
- STAR-AFS – Astronaut Flight Systems
- STAR-SCC – Spacecraft Commander

7 Certification Pathways

Certification designations within the STAR framework represent structured competency domains rather than specific courses or training programs. These designations are intended to be implemented by organizations within their own training environments while maintaining a standardized framework for certification and progression.

The STAR framework supports multiple certification pathways depending on professional background.

These pathways are illustrative examples of how competencies may be sequenced within the framework and are not intended to represent fixed or required training tracks.

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Figure 3 illustrates representative certification pathways within the STAR framework across multiple professional backgrounds.

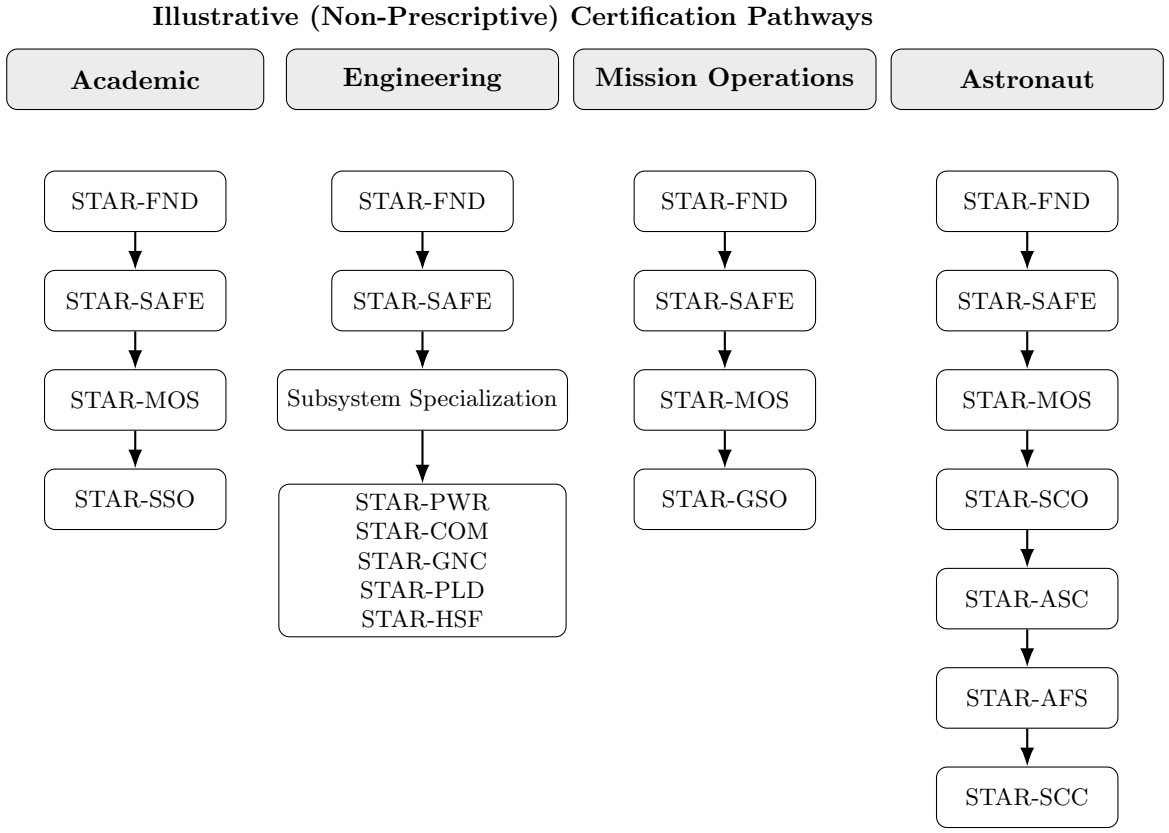

Figure 3: Representative certification pathways within the STAR framework. The pathways shown are illustrative examples of how competencies may be sequenced across academic, engineering, mission operations, and astronaut- oriented tracks within a common certification structure.

7.1 Academic Pathway

Illustrative progression within the framework:

- STAR-FND
- STAR-SAFE
- STAR-MOS
- STAR-SSO

7.2 Engineering Pathway

Engineers may pursue subsystem specialization certifications aligned with spacecraft systems engineering practice [3, 5] including:

- STAR-PWR – Power Systems
- STAR-COM – Communications Systems
- STAR-GNC – Guidance, Navigation, and Control
- STAR-PLD – Payload Operations
- STAR-HSF – Human Spaceflight Systems

7.3 Mission Operations Pathway

Illustrative progression within the framework:

- STAR-FND
- STAR-SAFE
- STAR-MOS
- STAR-GSO

7.4 Astronaut Pathway

Illustrative progression within the framework:

- STAR-FND
- STAR-SAFE
- STAR-MOS

- STAR-SCO
- STAR-ASC
- STAR-AFS
- STAR-SCC

These pathways demonstrate how individuals from diverse backgrounds may progress through a common certification structure while allowing for organization-specific training implementations.

8 Certification Assessment

STAR certification is awarded based on successful demonstration of competency through formal assessments designed to evaluate both theoretical knowledge and practical operational readiness.

Evaluation methods may include:

8.1 Written Examinations

Assess understanding of spacecraft systems, mission operations procedures, and spaceflight principles consistent with established aerospace engineering baselines [2, 5].

8.2 Simulation-Based Evaluations

Candidates operate within simulated mission environments to demonstrate decision-making, situational awareness, and operational discipline.

8.3 Operational Scenarios

Candidates respond to spacecraft anomalies and mission events, including telemetry interpretation and command procedure execution [7].

9 Certification Validity

STAR certifications remain valid for three years.

Recertification may be obtained through:

- Recertification examination
- Demonstration of operational experience
- Continuing education
- Participation in mission simulations

Certification states include:

- Active
- Expired
- Revoked

10 Governance and Program Administration

The STAR Certification Framework is administered by the RedMars STAR Program.

The STAR framework is designed to align with aerospace operational standards and regulatory guidance used throughout the space industry [12, 4].

10.1 STAR Certification Board

The Certification Board provides oversight of certification standards and program evolution.

Board responsibilities include:

- Reviewing updates to certification standards
- Defining competency requirements
- Maintaining technical accuracy
- Aligning certifications with industry practices

10.2 Industry Advisory Participation

The STAR program may establish an advisory council composed of professionals from the aerospace industry including:

- Commercial space companies
- Satellite operators
- Aerospace engineering institutions
- Government space agencies

10.3 Academic Partnerships

Universities may incorporate STAR certification preparation into aerospace engineering programs and CubeSat missions.

11 Long-Term Vision

The long-term vision of the STAR Certification Framework is to establish a widely recognized professional certification standard for spaceflight operations.

Over time, the STAR framework may evolve into an industry-recognized certification baseline similar to professional licensing systems used in aviation.

By defining clear competency standards and structured certification pathways, the STAR program aims to support a highly skilled workforce capable of operating future space missions.

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