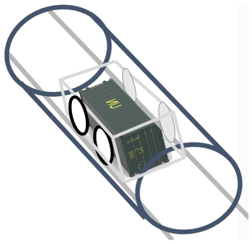
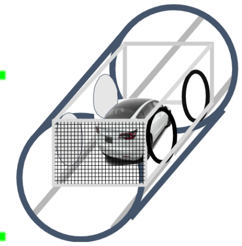


Swiftube



(A Different Approach to "Hyperloop")

This white-paper will discuss the elements of ***Swiftube,*** those that differ from Hyperloop, and reasons that it is a superior system that can be brought to production.

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Introduction:

The world needs to develop a sustainable means of global transportation of goods and people in order to meet climate goals and slow/extend the end of petroleum harvesting. The "Hyperloop" concept originated by Elon Musk and his team led us to imagine systems that promoted fast transport with minimal energy use. However, it appears that their 58-page white paper has established paradigms that have been detrimental to realistic or optimal system development. Their "Hyperloop Alpha" concept imagined travel within a capsule/pod contained in an evacuated tube. He believed that the drag forces inside of a tube (at atmospheric pressure) would make high-speed transport impossible. This assumption appears to have gone unchallenged by the broader Hyperloop community. Additionally, he projected that friction forces and dynamic instability of conventional (rail) wheels at high-speed make their use impractical. This is another case of unchallenged sentiment. Little thought appears to have been given to efficiencies that could be gained with multiple pods traveling together in a closed-loop tube. Finally, an evacuated tube presents the challenge of engineering pods that can withstand 14.6psi/100kPa, making larger pods capable of holding standard shipping containers impractical. Our ideal transport system would be flexible enough to carry as much as a full standard shipping container or up to tens of passengers between major cities, or transport a car and passengers the majority of a long drive, mostly at speeds approaching supersonic.

Proposal:

Swiftube (or whatever naming convention is adopted) is a closed-loop system that utilizes the pod/capsule-in-tube travel system similar to all Hyperloop developments. However, whereas traditional Hyperloop systems utilize magnetic levitation and vacuum tubes for capsule transport, ***Swiftube*** utilizes large-diameter wheels/hub motors (allowing high speeds at low RPM for dynamic stability) moved to the exterior of each capsule within a tube at normal atmospheric pressure that is 99.7%+ treated in the latest lowest-drag coating. This simpler system supports a more cost-effective solution, allowing faster testing and building to bring global tubed-travel to realization before the end of the century. ***Swiftube*** system efficiencies and speeds are further improved with both more utilization (reducing the space between capsules), lower-drag coatings as they are developed, and more (solar) power is employed in years to come. Initial calculations indicate that speeds of 210km/h are feasible with pod spacing of over 2 km apart. Speeds can increase by ~42% when the space between pods is halved (traffic doubles) and the power is evenly split between the pods (double the power). The same is true as new coatings are developed that reduce drag by half. One might then ask, “Why not just apply the coating to high-speed trains and not use tubes?” The reason is that open-loop high-speed trains push/pull air continuously on the front and rear of the train, respectively, as well as within the undercarriage and everywhere a seam or imperfection exists. Tubed travel conserves the momentum of the ‘slugs’ of air between pods, making it much more efficient than conventional travel modes when distances between pods are less than about 2km.

Additional ***Swiftube*** benefits include:

- Weather is an irrelevant factor in ***Swiftube*** (or Hyperloop) travel.
- Most capsules fill roughly 94% of the tube diameter, effectively acting as a piston. This precludes (or at least highly limits the effect of) collisions between pods.
- Likewise, crashes/derailments inside of a tube would result in far less serious outcomes, as the pod would be contained within the tube throughout any event.
- Pods can be used in virtually limitless configurations, transporting people, their cars, goods, and nearly anything else.
- A robust ***Swiftube*** loop would incorporate a nuclear power backbone, with solar and wind supplements to limit the use of nuclear power. The system would also be tied into a country’s power grid, improving overall grid resiliency.
- Emergency pod exits are available to quickly escape a burning pod. Tube exits would be determined at intervals that would allow people to escape quickly, unharmed.
- As a contained system, the ability for terrorists to inflict wide-scale destruction is negligible. X-ray screening of luggage pieces is recommended, but otherwise it is no different than riding a subway.

Swiftube ”ports” (known as “Swiftports”) will be interconnected with major airports approximately every 150-250 km. This would allow passengers to fly to/from regional airports, but utilizing ***Swiftube*** for the largest segment of travel. Additionally, major freight hubs would have their own Swiftport centers for shipping/receiving goods. Here, shipping containers would be loaded onto a truck for local/regional delivery.

Within any given country, the hours of ***Swiftube*** operation should normally be 0600 to 2400, with midnight to 0600 reserved for track safety checks and maintenance. In countries with multiple time zones like the United States, other creative solutions may be outlined. Maintenance vehicles could be equipped with stopper-like devices that would effectively seal a tube, in order to ensure the safety of work crews.
Upon opening for the days’ operations, smaller passenger pods would enter the tube first, allowing both faster speeds for the smaller pods, and getting the air circulating within each segment of tubing between interchanges and beyond. Larger pods would follow, both utilizing the existing airflow begun by the smaller pods, and pushing the air masses between cars to even

higher speeds. As the volume of traffic increases and new coatings decrease drag over the years, the overall speeds and efficiencies will increase to nearly the speed of sound and perhaps beyond (after significant testing, of course).

My ***Swiftube***/Hyperloop Journey:

I have lived in Suffolk, Virginia, USA since 2000. Thanks to our large naval base and port in nearby Norfolk, we have many tunnels traversing the nearby waterways. Many years ago while driving through a one-way tunnel (at 55 mph / 90 km/h) with the window down and my hand outside, I noticed that the air resistance against my hand dropped dramatically when entering the tunnel and raised again upon exiting. Over several years, I've repeated my little experiment and found it to hold true, with the magnitude of resistance proportional to the amount of traffic in the tunnel. I also observed that the effect was still significant even when there were no vehicles ahead of me (only behind) before the exit of the tunnel.

I was out to dinner with coworkers on a work trip to San Diego in 2018 when I described my observation and made the claim that we "really need a series of tubes along our Interstate system with pods going nearly supersonic speeds." My coworker, Matt, turned to me and said, "Do you mean Hyperloop?" He shared that Elon Musk had talked about it a few years before. Since then, I've followed Hyperloop development, and grown increasingly frustrated with the development path taken with magnetic levitation and vacuum tubes. It is clear to me that paradigms have formed in the community against conventional travel within a tube. I want to break these down, while keeping the design open to someday (upon the advent of high-temperature superconductors) incorporate magnetic levitation.

Naming Convention:

Elon Musk has become a controversial personality in the United States, and possibly internationally as well. As such, it will become very difficult to garner the political will to make "Hyperloop" a viable venture in the U.S. Although I am fond of the "***Swiftube***" moniker, I am happy to bow to any system name that can bring tubed travel into wide-scale production.

Steps for Development:

For any tubed travel system to develop into a global system for transporting goods and passengers, we MUST set (as a minimum) the following standards:

- Standard tube inner-diameter. 4.2m is proposed with a maximum pod diameter of 4.0m.
- Standard track width. 2.9m is proposed, allowing room for a standard shipping container to fit within a pod.
- Standard power supply for the system. 6.6kVAC is proposed in order to effectively and efficiently transmit power to each pod.
- Pods will need to be capable of utilizing both 50Hz and 60Hz power supplied.
- Standard IT protocols for transmitting/receiving pod and tube data globally.
- Redundant systems using (a minimum) of 2/3 (2/4 is proposed) independent processing for speed control, steering control, and all other vital functions.
- System Testing within a loop that is no less than one-fifth the size of actual size, and at least 50km in length.

- Simplistic tube design with structural supports that are adjustable and isolated from earthquakes, plate tectonics, and locally anticipated natural disasters (tsunami, hurricane)
- Once a full loop is implemented and tested within one country, the system can expand into multiple countries, and eventually globally.

Hypothesis, Recommendations, and Conclusions,:

Tubed, closed-loop travel within ***Swiftube*** will improve the efficiency, safety, and speed over all current forms of travel. One hypothesis is that the closed loop would significantly improve the efficiency of moving air (conservation of momentum). However, the more likely hypothesis is this will not change the energy requirements, as drag exists regardless of it being in an open loop or closed loop.

Other considerations:

- Hyperloop systems offer superior speed and possibly lowest energy costs (until near-zero drag coatings are developed).
- Hyperloop construction costs are estimated at $55M/mile (€30M/km). Complex energy delivery (superconductors), tube, and control systems dominate cost.
- ***Swiftube*** construction costs are less than ⅓ that of "traditional" Hyperloop systems. Specifically, using mostly PVC/HDPE compared to steel and simpler pod design, energy delivery, and pod propulsion. However, complex and redundant controls are still needed.
- ***Swiftube*** systems rely on minimizing drag of the tube itself, compared to Maglev and vacuum tube challenges.
- Hyperloop vacuum tube systems can't realistically incorporate freight (half of transportation-related greenhouse emissions).
- ***Swiftube*** systems are inherently safe with high-volume and offer quick escape in an emergency.

As described in the backup calculations and testing section, I urge there to be two tests consisting of:

(1) A 1/42nd size model (without power, just vehicles accelerated by gravity) to validate the tube physics.

(2) A 1/4 size model with power to validate large-tube modeling and power assumptions.

Initial full-scale systems could be built between major cities, like between Berlin and Hamburg, Busan and Seoul, or Dallas and Houston. Once the concept is proven, then further intra-national and international development could blossom. If an internationally recognized standard for rail width, tube diameter, IT protocols, and power flexibility/requirements exists, the international system integration could be seamless.

Tubed travel of any sort is the only way to meet our global energy and transportation challenges towards the 22nd century. Closed-loop systems eliminate or nearly eliminate weather delays and crashes, while improving the speed and efficiency with which we move goods and people. ***If we get it right***, it will serve mankind well for centuries to come.