Team HyperLift Performs in SpaceX Hyperloop Competition using Sparton AHRS

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NAVIGATION AND EXPLORATION

Overview

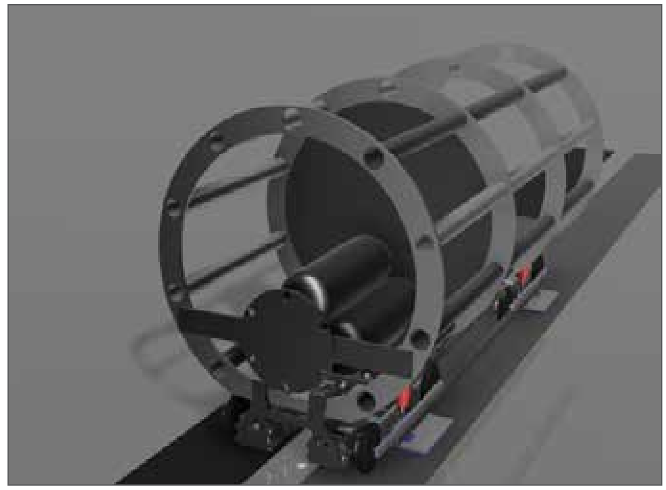
A hyperloop is a mode of transportation where a pod travels through a tube at very high speeds. The idea is based on the theory that pods travelling free of air resistance or friction can do so at an optimal speed. Elon Musk, the founder of SpaceX, has been a leader of the concept and in the promotion of Hyperloop as an efficient mode of high-speed travel and transportation. So much so, that Musk and SpaceX have actively promoted an open-source model and have encouraged others to take ideas and develop them.

In June of 2015, SpaceX announced that it would sponsor a Hyperloop Competition for pod design and built a mile long test track near their Hawthorne, California headquarters. More than 700 teams submitted preliminary applications before detailed competition rules were even released. That total grew to over 1000. Of those, 120 teams were selected to submit final designs before a Design Weekend in early 2016. From there, 30 teams were selected to advance to the Competition Weekend in early 2017. Team HyperLift was one of those 30 teams.

Not only is that quite an accomplishment in itself, being one of thirty finalist teams from around the world, but Team HyperLift is a group of six high school students from St. John's School in Houston, Texas. They were the only high school team to go that far in the competition. But, being the highly motivated group individuals that they are, they were not deterred by competing against undergraduate and graduate students or even doctorate candidates.

Team HyperLift (teamhyperlift.com) entered the competition with the goal of providing the safest, most reliable, most cost-effective, and most efficient Hyperloop pod design through the implementation of innovative designs.

How did they do? Team HyperLift placed 9th in the SpaceX Hyperloop Pod competition. They received an Honorable Mention for Performance and Operations and were the first team to have a successful levitation test in the vacuum test track.



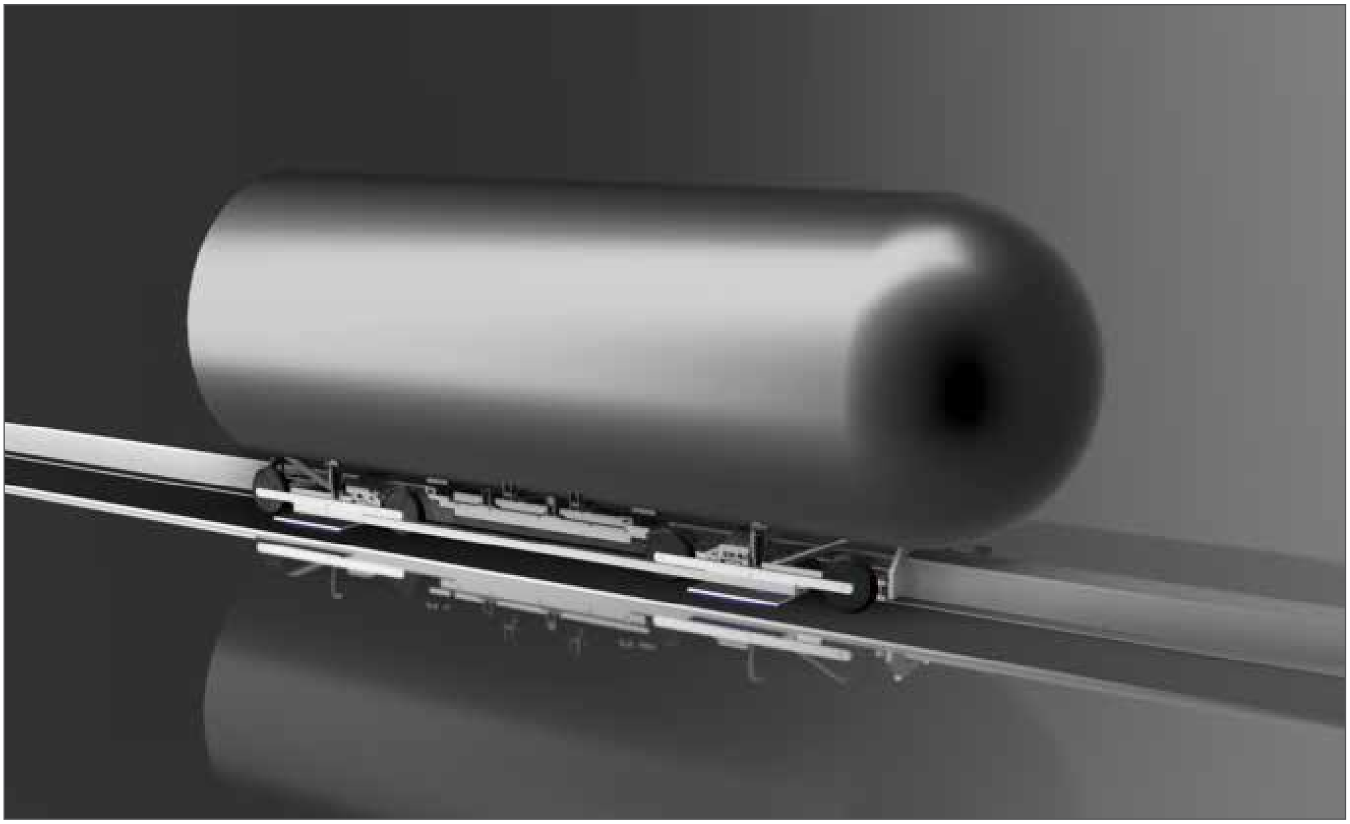
Above:
Rendering of Pod framework.

Technical

One of the electrical challenges in the design of a Hyperloop system is the use of steel tubing used to create the low-pressure required to allow the transportation tube to travel in a near frictionless environment. With the necessary grounding, the steel tubing acts as a Faraday cage that cause's limited signal reception within the tube. An internal network allows for control communication, but insufficient GPS signal. Limited GPS leaves the pods with a choice of either color distance determination using tape along the surface of the tube or the use of inertial navigation systems (INS) for navigation. Team HyperLift chose to use both systems, but would use the INS as the primary system due to its accuracy.

With potential pod speeds in excess of 200 mph, the Team was not able to get accurate distance determination using non-calibrated Microelectromechanical Systems (MEMS) Inertial Measurement Units (IMUs). The sampling rate as well as the accuracy of measurements using off-the-shelf MEMS-based IMUs was not reliable enough for the Team to effectively use them.

Team HyperLift turned to Sparton and inquired about the AHRS-8P, an Attitude Heading Reference



Above:
Rendering of fully built Pod.

System. The AHRS-8P would allow the Team to simplify many aspects of their design, including on-board digital filtering. Using the AHRS-8P allowed HyperLift to eliminate the need for external filtering circuits that could be problematic.

For Team HyperLift, the main benefit in using the Sparton AHRS-8P over other products was the systems' purely inertial approach – absent filtering techniques that utilize reference points such as GPS or GLONASS. With the previously mentioned limited signal reception within the tube, such features would prove to be impractical, if not cumbersome.

The Team would use a control system run on a Hummingbird Pro – a single board computer running Linux with powerful computing capabilities. The main challenge in the implementation of such a control system would be the correct filtering – allowing computing resources to be used efficiently so that the inertial navigation system could run as fast as possible. The Team would use MATLAB to develop and fine tune the algorithm before incorporating it into their Python control system. Appropriate telemetry information including velocity, distance travelled, attitude, and reference data would be streamed over a Universal Datagram Protocol to the ground station for monitoring. HyperLift used two AHRS-8Ps in order to gain both redundancy and improved accuracy using the average of the two sensor systems. The use of two Inertial Sensor Systems would ensure the safety of the pod as well as the entire system as INS failure would be catastrophic.

Application

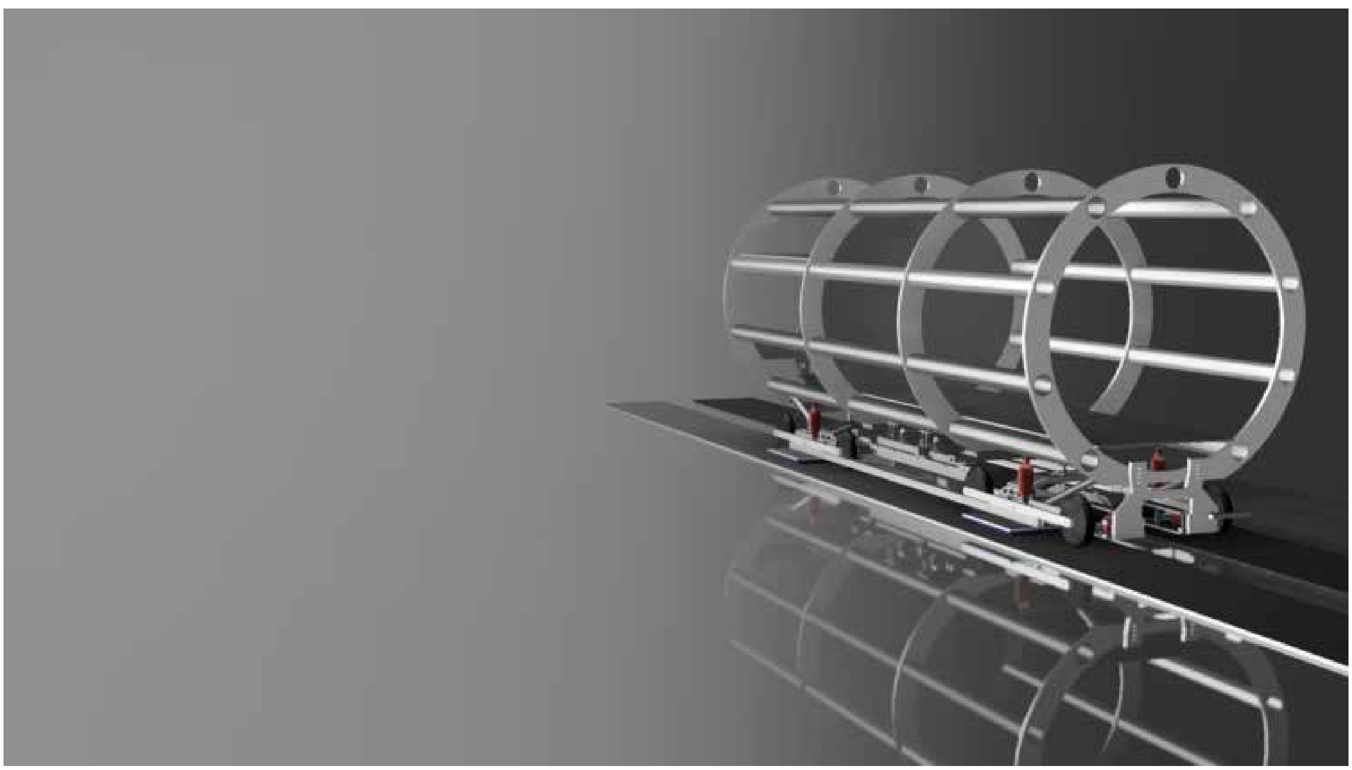
The implementation of an Inertial Navigation System was initially daunting; especially with using an Extended Kalman Filter. Sparton's assistance and expertise proved to be vital in the development of Team HyperLift's own system. The hardware capabilities as well as Sparton's willingness to provide assistance in the Kalman filter implementation were greatly appreciated by the Team.

The telemetry Team HyperLift used for their pod included battery statistics, position within their state diagram, and general position and velocity of the pod. The Team used the Sparton AHRS-8P as their onboard accelerometer and gyroscope.

SpaceX's biggest concern was HyperLift's ability to brake once the propulsion vehicle detached from the pod. The Team used both physical switches and the 8P to detect major changes in the acceleration of the pod to determine when the propulsion vehicle had detached. HyperLift also used the 8P in conjunction with a tachometer along the wheels to determine position and speed within the tube.

The Sparton AHRS-8P was used to get an approximation of velocity as well as trigger phase changes within their control scheme. Integrating the 8P into the control system was seamless. The Team chose to use data already filtered through the sensor's AdaptNavTM algorithm which provides real-time (non-linear) sensor heading optimizations, creating a straightforward solution to their system's attitude and heading needs.

"Team HyperLift is incredibly thankful for all of the assistance Sparton provided our team," said Robert Gottschalk, Team HyperLift's Head of Electronics. "We could not have delivered our proof of concept without the invaluable data provided by the Sparton AHRS-8P."



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Pod framework.