Elon Musk shows off Interplanetary Transport System
By Derek Richardson

In a presentation akin to something out of science fiction, Elon Musk, founder and CEO of SpaceX, announced the Interplanetary Transport System (ITS). The two-stage rocket would be bigger and send more payloads to orbit (and beyond) than anything in the history of spaceflight.

At the 67th International Astronautical Congress held in Guadalajara, Mexico, Musk detailed the components of ITS – a giant booster stage with a giant spaceship totaling 400 feet (122 meters) tall. The NewSpace entrepreneur's discussion was titled "Making humans a Multiplanetary Species".

The booster stage would be 254 feet (77.5 meters) tall and 39 feet (12 meters) wide. It would sport 42 raptor engines at the bottom – coincidentally, the same number as the "Answer to the Ultimate Question of Life, the Universe, and Everything" in one of Musk's favorite books, The Hitchhiker's Guide to the Galaxy.

The spaceship, which doubles as an upper stage, would be 162 feet (49.5 meters) long and 56 feet (17 meters) wide. It would have a total of 9 engines (3 sea-level and 6 vacuum versions).

The expendable version of the rocket would be able to take 550 metric tons to low-Earth orbit (LEO), while the fully reusable version would take 300 metric tons. After being refueled on orbit, it could take up to 450 metric tons to the surface of Mars.

"It's quite big," Musk said after showing off the basic numbers. "In the long term, the ship's will be even bigger than this. It needs to be about this size because in order to fit about 100 people in the pressurized section plus carry the luggage and all the unpressurized cargo to build propellant plants and build everything from iron foundries to pizza joints."

Musk said that while he won't be on the first ship, he hopes to name it Heart of Gold – after the ship with the Infinite Improbability Drive from The Hitchhiker's Guide to the Galaxy.

"I like that it is driven by the Infinite Improbability Drive because our ship is also improbably," Musk said.

THE INTERPLANETARY TRANSPORT SYSTEM

The whole system would launch from Kennedy Space Center's Launch Pad 39A. The rocket's first stage would have a similar launch profile as the Falcon 9. It would launch, and at stage separation, turn around and fly back to the launch site.

Then the upper stage, which is also the spaceship, would continue burning for orbit. Once in orbit, it would be refueled by a "tanker" version of the spaceship. After it is fully fueled, it makes

the burn for Mars.

According to Musk, depending on what planetary alignment you use, you could get to Mars in as little as 80 days with the ITS.

After landing on the Red Planet, it would refuel using in-situ propellant production to create the liquid oxygen and methane fuel. It would then launch directly back to Earth and land.

Once back on Earth, it would be prepared again for another journey to the Red Planet.

Both the rocket booster and spaceship would be powered by Raptor engines that the company is currently developing.

Musk said SpaceX is targeting reusing the booster up to 1,000 times, the tanker 100 times and the Mars spaceship 12 times.

THE RAPTOR ENGINE

SpaceX has been testing their successor to the Merlin engine for a couple of years now. Only recently did the company ship the engine to the test stand at McGregor, Texas. On Sept. 26, the engine was fired for the first time, albeit briefly.

Musk thanked his team for working seven days a week to get the first test firing done before the IAC announcement.

The engine is a full-flow staged combustion engine – one of only three that have ever developed to the point of testing. It has a chamber pressure of 300 bars – three times that of the Merlin 1D. This allows the engine to be powerful, but still small. In fact, Musk said the engine will be about the same size as the Merlin engines.

The engines will consume subcooled liquid oxygen and subcooled liquid methane, similar to what the company's current rocket, the Falcon 9, does with liquid oxygen and rocket-grade kerosene.

The engine will be able to throttle between 20 percent and 100 percent of rated thrust. At sea level, its thrust will be 685,700 pound-force (3,050 kilonewtons) with a specific impulse (Isp) of 334 seconds. In vacuum, the engine will have 786,800 pound-force (3,500 kilonewtons) of thrust with a 382 second Isp.

THE ROCKET BOOSTER

Using 42 of these engines, the boost stage, which does not yet have a name, will accelerate the whole stack – including the spaceship on top – to a velocity of 5,375 mph (8,650 km/h) at stage

separation.

The booster will then return to the launch site using only 7 percent of the total booster propellant load. Grid fins will guide the giant rocket back for a precise landing – on the launch mount.

“We’re getting quite comfortable with the accuracy of the landing,” Musk said. “With the addition of some maneuvering thrusters, we can actually put the booster right back on the launch stand. Those fins at the base [of the rocket] are essentially centering features to take out any minor position mismatch at the launch site.”

The base of this booster will have a central cluster of seven Raptor engines that can gimbal and steer the rocket. The rest of the engines will be clustered in two rings around the center. The inner ring will have 14 engines, while the outer ring will have 21. These rings of engines will be fixed in place as they will not be needed for steering.

The tank that would hold the densified fuel would be made of carbon-fiber, as opposed to the aluminum-lithium alloy the Falcon 9 uses. Additionally, these tanks would not be pressurized by helium but by the gaseous version of the methane and oxygen. These gasses would also be used as thrusters for both the booster and spaceship.

On takeoff, the total thrust of the vehicle will be 28.8 million pound-force (128 million newtons).

“It’ll be quite tectonic when it takes off,” Musk said. “They sort of over-sized the pad in doing Saturn V. As a result, we can actually do a much larger vehicle on that same launch pad.”

THE INTERPLANETARY SPACESHIP

As for the spaceship, it also doubles as an upper stage. It would reach orbit with its tanks nearly empty. On top of the tanks would be a cargo and living compartment with space for up to 100 people for a journey to the Red Planet.

“This vehicle [system] is intended to carry huge numbers of people, possibly millions of tons of cargo to Mars,” Musk said. “So, you really need something quite large in order to do that.”

Once it gets into orbit, it would need to be refueled. That would be done by launching a similar version modified to only carry propellant. It could take up to three to five of these “tankers” to refuel the spaceship.

Once fully fueled, and the planets align – occurring once every 26 months – the burn for Mars can occur.

With its nine engines, it would have a total vacuum thrust of 6.97 million pound-force (31 million newtons). This would allow it to take the 450 metric tons of humans or supplies to Mars.

Once on its cruise to the Red Planet, the spaceship would deploy two massive solar arrays to generate a total of 200 kilowatts of electricity. Musk also believes this is enough power to refuel the ship after it lands on Mars.

TIMELINES

Musk has a history of being overly optimistic on timelines. Some have deemed this “Elon Time”. However, he left the timeline for developing the Interplanetary Transport System intentionally fuzzy.

The SpaceX CEO wants the first development spaceship built in four years to start doing suborbital flights with it – similar to the Grasshopper program that lead to reusable Falcon 9 first stages.

The booster rocket, Musk believes, is pretty straight forward. He said it involves scaling up the technology from Falcon 9.

“Not a lot of showstoppers there,” Musk said.

However, he pointed out testing the system together will take a lot longer.

“If things go well, it’ll be in the 10-year timeframe,” Musk said.

But Musk won’t wait for that. SpaceX plans on sending a modified unpiloted Crew Dragon, called Red Dragon, to Mars in 2018.

After that, SpaceX plans to send at least one capsule to Mars during every Mars rendezvous opportunity to deliver up to 3 metric tons of usable cargo or science equipment on the surface.

Additionally, the company has started testing the Raptor engine as well as a developmental carbon fiber cryogenic oxygen tank for the spaceship. In fact, Musk said that tank was finished.

“This is really the hardest part of the spaceship,” Musk said. “The other pieces, we have a pretty good handle on, so we wanted to tackle it first.”

Musk said by putting supercooled liquid oxygen and methane inside the tank, it could crack and leak. However, preliminary tests on the development tank have shown neither problem. He said the sheer scale of building these tanks is also challenging as you have to lay out the material the right way on a huge mold, cure the mold at temperature, etc.

“It’s just really hard to make large carbon fiber structures that can do all of those things and carry incredible loads,” Musk said.

THE LONG GAME

Musk believes Mars is the best candidate in the Solar System to begin building a self-sustaining multi-planetary species. He said that early Mars was a lot like Earth and if humans could warm the planet up, it would once again have a thick atmosphere.

In order for enough people to make the trip through interplanetary space, the cost needs to be low enough. Musk believes that cost needs to be around $200,000.

To do that, Musk believes four technologies must be developed and perfected: Full reusability, refueling in orbit, propellant production on Mars, and the right propellant.

Without refueling in orbit, Musk said, the cost would be at least five times higher. Additionally, not refueling would require a three-stage booster. If the system were three stages, then it would need to be five to ten times the size and cost on top of that.

As far as fuel, the company chose methane because it is readily available to produce on Mars and is much easier to handle. While hydrogen is more efficient, it is harder to handle.

“Methane is better almost across the board,” Musk said.

Musk said whatever system is designed, whether it is by SpaceX or someone else, these are the four areas that need to be solved.

As for ITS, he said it would look almost exactly like what was shown today. The simulation was made by the SpaceX engineering computer aided design models.

“This is not what it might look like,” Musk said, “It is what we plan to make it look like.”

Musk said that in the future, the ships would need to be even bigger than this. It is already this big because it needs to fit about 100 people inside.

Using ITS, Musk said that to get a million people on Mars, you’d need 10,000 trips. Once the first one goes to the Red Planet, he estimates it would only take 40–100 years to get a fully self-sustaining civilization on Mars.

BEYOND MARS

Additionally, Musk said that the system can open up the entire Solar System to people. If fuel depots based on this design were put on asteroids or other areas around the Solar System, people could go anywhere they wanted just by planet or moon hopping.

“The goal of SpaceX is to build the transport system,” Musk said. “Once that transport system is built, then there is a tremendous opportunity for anyone that wants to go to Mars to create something new or build a new planet.”

MUSK AND MARS

In a bid to make spaceflight cheaper, Musk started SpaceX. It took the company four tries to get into orbit. The first successful launch was flight 4 of the Falcon 1. Image Credit: SpaceX

Musk’s Mars ambitions go back even before SpaceX was founded. Before he knew much about rocketry, he met with members of the Mars Society at a fundraiser mid-2001 – a $500 per plate event at one of the members’ homes.

Musk invited himself and paid $5,000. Robert Zubrin, the head of the Mars Society, took note and invited him to coffee prior to the dinner to tell him about the society’s accomplishments and goals, including a plan to send a capsule into orbit carrying a crew of mice. The mice capsule would spin to give it one-third gravity – the gravity on Mars. The mice would live and procreate.

After the talk, Zubrin placed Musk at the VIP table next to himself as well as James Cameron and Carol Stoker – planetary scientists for NASA.

After joining the society’s board of directors, Musk donated another $100,000 for the Mars Desert Research Station in Utah.

This was around the time PayPal was being sold to Ebay for $1.5 billion. Musk was the largest shareholder.

Soon, Musk started thinking beyond the Mars Society’s goals. He wondered about the possibility of sending the mice to Mars.

Not long into the mice-to-Mars discussion, the goal took on a new form – sending a robotic greenhouse to Mars to grow plants. It seemed doable and bold. The idea was to have a live video feed to people could watch the plants grow – the first life on Mars.

TOO EXPENSIVE

However, as he and his small team of engineers started digging into the idea more, they found it more complicated than first imagined. Additionally, Musk’s trips to Russia to acquire an intercontinental ballistic missile were a waste of his time as the Russians either didn’t take him seriously or were wanting to take as much of his money as they could – possibly both.

Musk came out of 2001 and early 2002 realizing the cost of sending a payload into space was too much. So, in June 2002, he founded Space Exploration Technologies to radically change

the way the space industry thinks about rockets.

At a minimum, Musk has done that. And now with today's Interplanetary Transportation System announcement, he is poised to go farther and bolder than any successful aerospace company to date.

But who will pay for this plan?

SHOW ME THE MONEY

SpaceX has done a lot in its more than 14 years as a NewSpace company. All of the Falcon 1 was privately funded, much of it through Musk's own checkbook. However, in 2006, SpaceX started receiving Space Act Agreements from NASA to help them with their Dragon capsule. In 2008, they would be one of two companies to get a Commercial Resupply Services contract to send cargo to the International Space Station.

That money, in addition to other investors and Musk, helped accelerate both Dragon and the Falcon 9 v1.0 rocket. Musk has repeatedly stated that without NASA money, it would have taken longer than it actually did.

Dragon and Falcon 9 both flew in 2010. Regardless of where the money came from, SpaceX estimated in 2011 that the total developmental cost of the rocket to be around $300 million. NASA estimated that with traditional cost-plus contracts, it would have been $3.6 billion.

Between Dragon and Falcon 9 v1.0, NASA provided $396 million and SpaceX provided more than $450 million.

COMMERCIAL REVENUE

Today, SpaceX gets its revenue from more than just NASA, although the U.S. space agency remains the company's largest customer. Much of the Falcon 9 first stage reusability efforts have been financed from the profits the NewSpace firm has made from these missions.

It also helps that for each mission, after the first stage detaches, it is essentially a free test.

The company has also upgraded Falcon 9 to a new Full Thrust variant and boosted the Merlin 1D engine's performance to make it one of the most efficient American-made hydrocarbon engines. None of that could have been done up front. It took many years from the Falcon 1 to today.

PAYING FOR THE INTERPLANETARY TRANSPORT SYSTEM

Elon Musk tweeted this picture of SpaceX's Raptor engine during its first test firing. Photo Credit: SpaceX

So who will pay for Musk's next chapter of SpaceX history? No doubt Musk and SpaceX will go it alone if they have to, but they would likely not achieve the already ambitious timeline without some funding help – likely from NASA.

Right now, however, NASA isn't interested in funding a commercial alternative to the Space Launch System or Orion.

As things stand now, SpaceX is allocating less than 5 percent of the company on ITS and spending only a few tens of millions.

Musk expects to spend more resources on the project as SpaceX finishes development of the final version of the Falcon 9 and Dragon 2 and get reusability of the Falcon 9 first stage and Dragon 2 sorted out.

"Within a year-and-a-half to two years, most of SpaceX will be on the system," Musk said later in a question-and-answer session.

After that, Musk hopes the company will devote about $300 million a year to the project. Overall, he estimates the total developmental cost to be around $10 billion.

For the production vehicles, Musk estimates it would cost $230 million to build the booster, $130 million to build the tanker, and $200 million to build the spaceship. That means if the company just built one of each, it would be over a half-billion dollars.

Musk estimates that one flight to Mars using ITS could cost around $62 million, about the same as one Falcon 9 today.

To pay for the trip, after everything is developed and tested, Musk expects people to hand over less than $200,000 per person – a price he expects to lower as the system optimizes.

FUNDING SOURCES

However, as far as development funding goes, Musk wasn't shy to say that there wasn't much at the moment. In a slide, he showed funding sources ranging from launching satellites, sending cargo and astronauts to the International Space Station, Kickstarter to even stealing underpants.

The last option was a reference to an episode of Comedy Central's South Park in which the main characters do a presentation on gnomes who steal underpants to make a profit – a three phase business plan with no visible path to success.

Musk said a lot of people in the private sector are interested in funding Mars bases, but he insisted that this would have to be a huge public-private partnership.

“That’s how the United States was established,” Musk said.

He said SpaceX is trying to make as much progress as it can with the limited resources it has available.

“I think as we show this is possible, that this dream is real, I think the support will snowball over time,” Musk said. “The main reason why I’m personally accumulating assets is in order to fund this.”