



ARIZONA FORGE

Space Tourism

Stephen Fleming

Executive in Residence

 @stephenfleming





Who Am I?

3 years as Vice President, University of Arizona

Corporate engagement, Arizona Space Business Roundtable, and more...

**11 years as Vice President,
Georgia Institute of Technology.**

Responsible for economic development, including commercialization, corporate engagement, manufacturing support, incubators, accelerators, ecosystem development, and more. Helped create and launch NSF I-Corps program.





What Did I Do Before?

10 years VC experience at General Partner level:

18 investments as lead investor

*12 profitable exits (including 4 IPOs,
one \$650M acquisition)*

47% annualized cash-on-cash IRR

15 years corporate operations:

AT&T Bell Labs

Nortel Networks

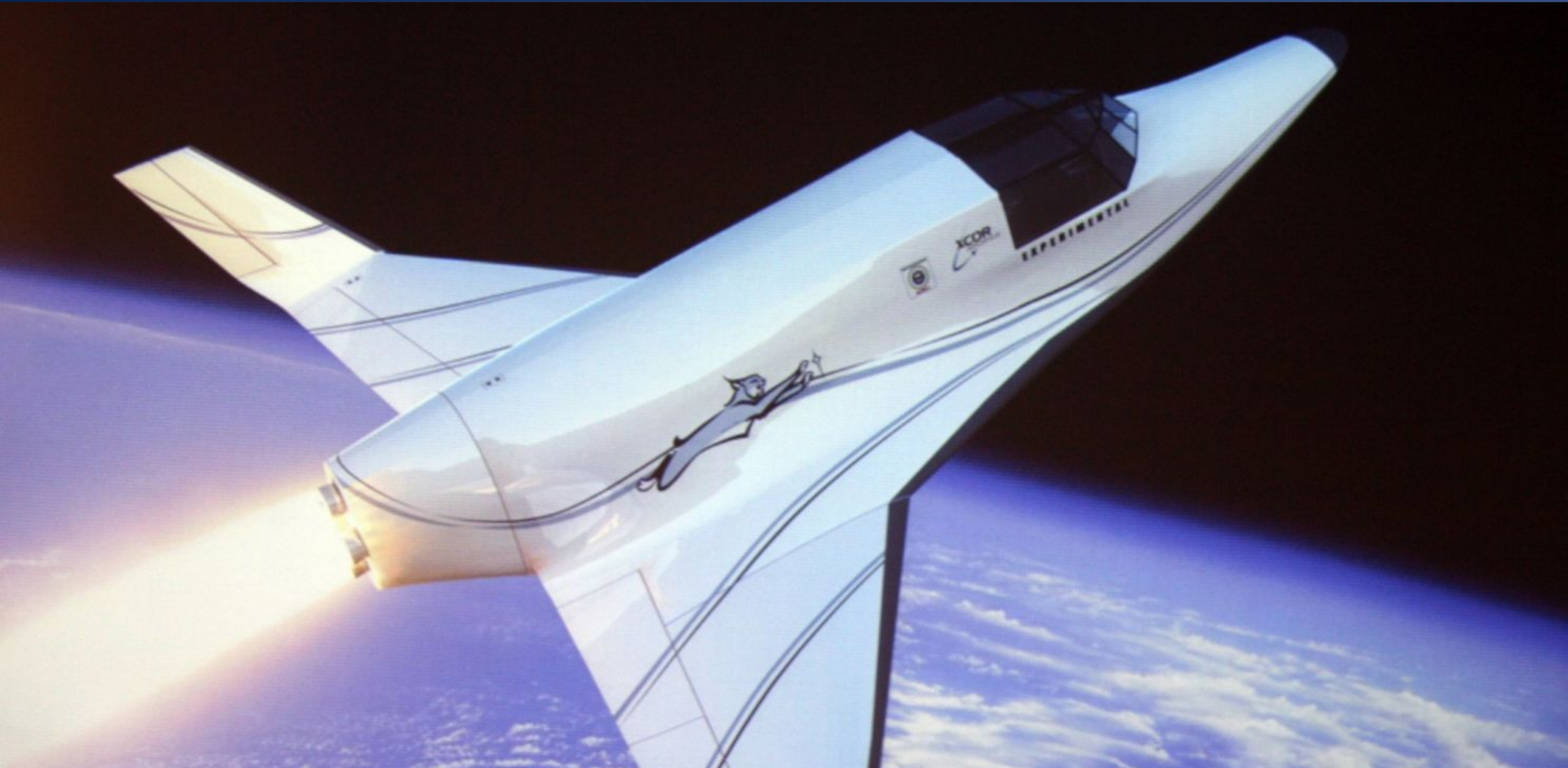
LICOM (venture-backed telecom equipment startup)

BS, Physics, Georgia Tech (*Highest Honors*)





XCOR Aerospace



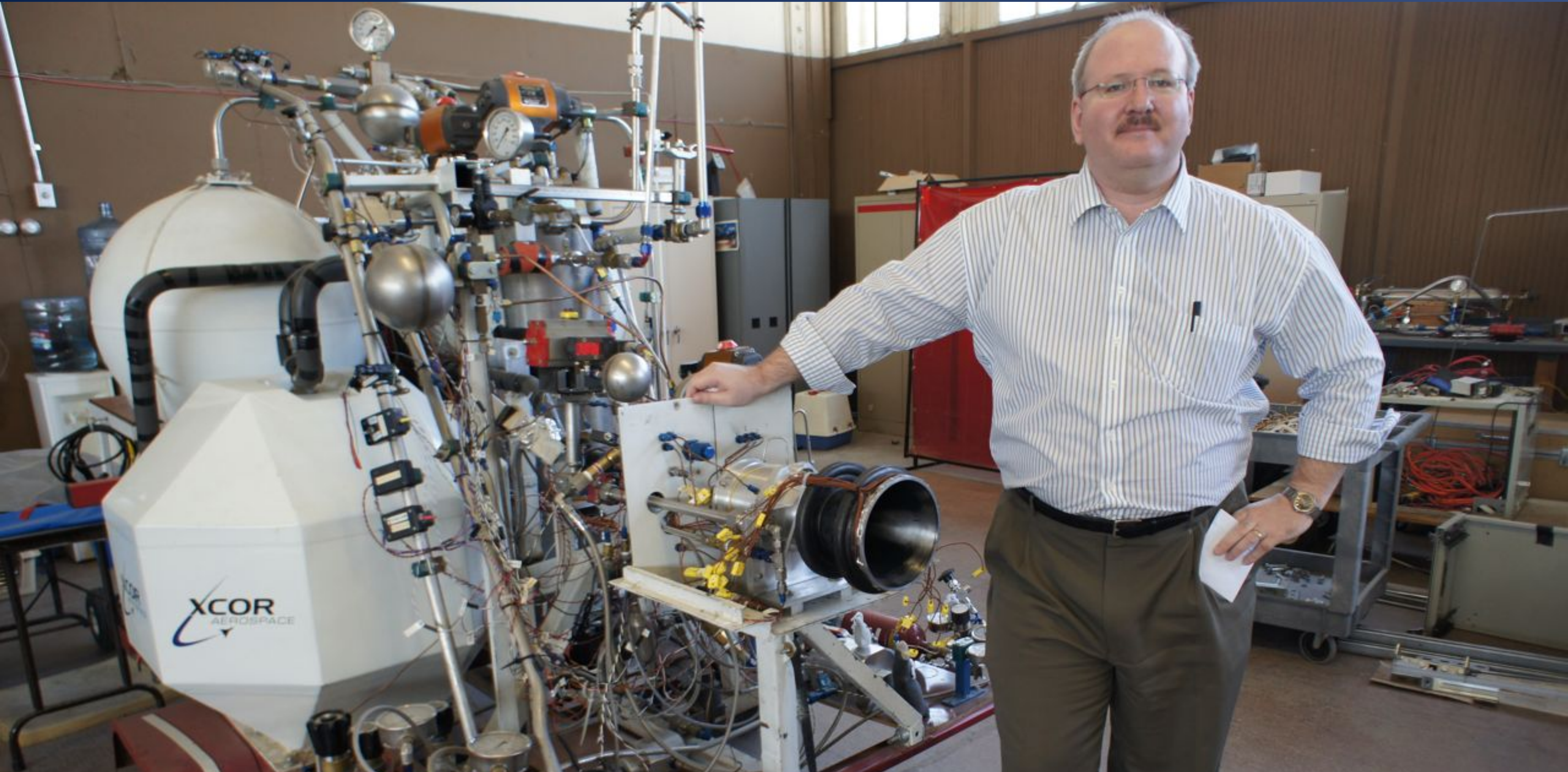


XCOR EZ-Rocket 2001





Liquid-Fueled Engine Development





XCOR Rocket Racer *June 2008*





XCOR Development





XCOR LOX-Methane Engine Development





XCOR Development



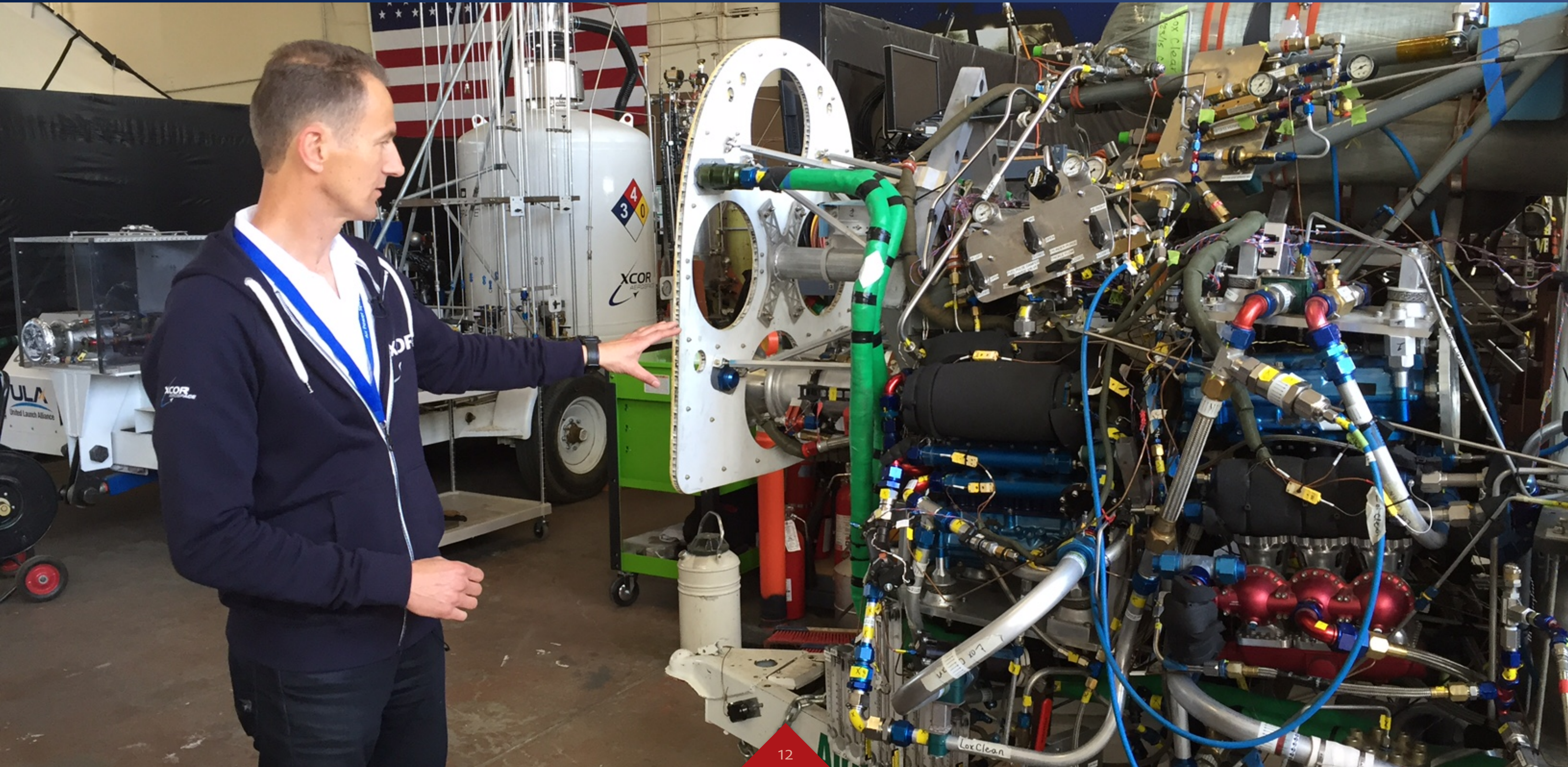


XCOR Component Testing





Rocket Plumbing





XCOR Flight Operations

Flight Operations



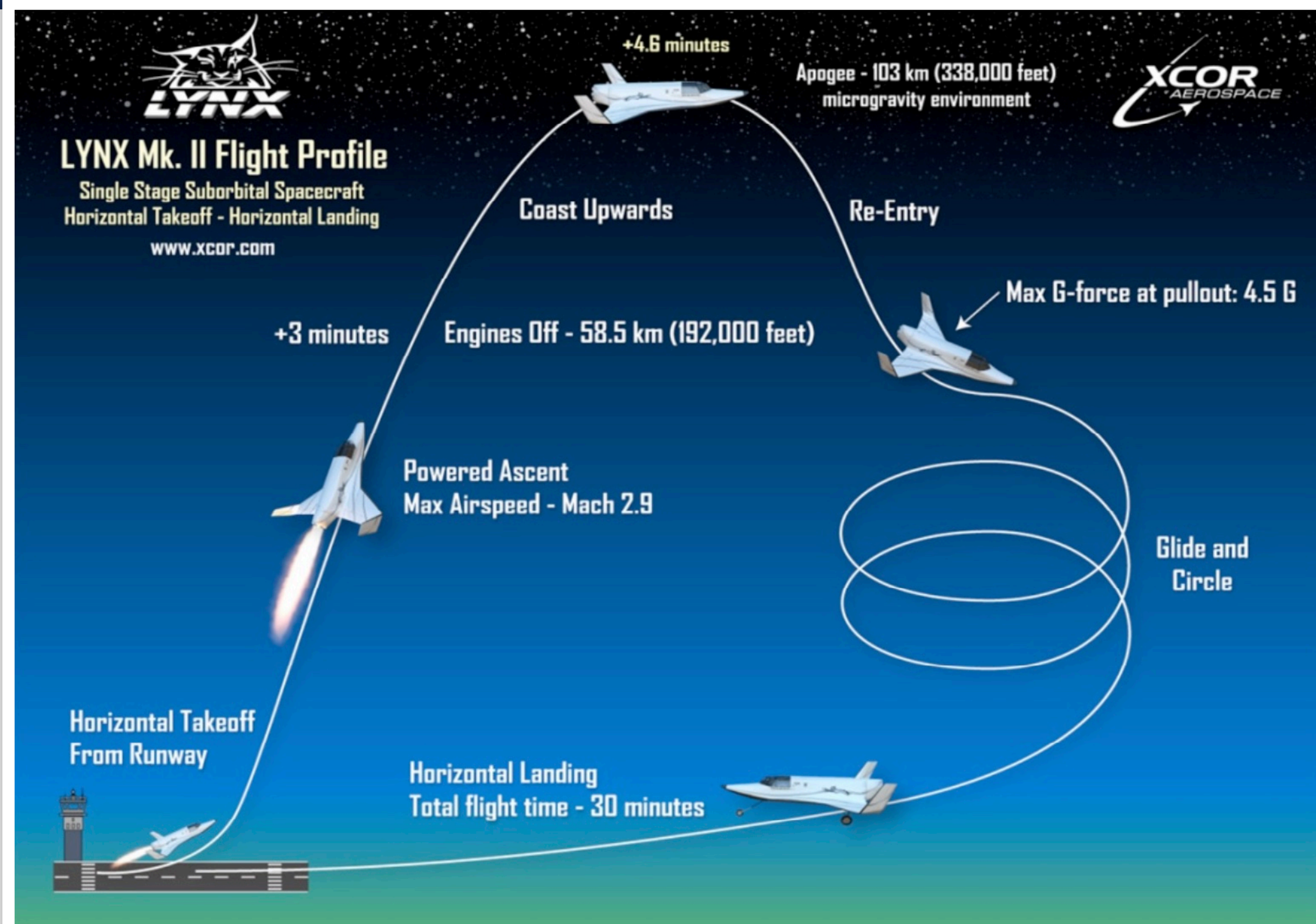
- **Aircraft-like operations from any airport with a 7,000-foot (2,100 m) runway and appropriate airspace**
- **Fast turnaround**
- **Low maintenance: 2 hour engine runtime overhaul intervals**
- **Up to 4 sorties per day**
- **Weather/seasonal constraints: winds**

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XCOR Lynx Flight Profile



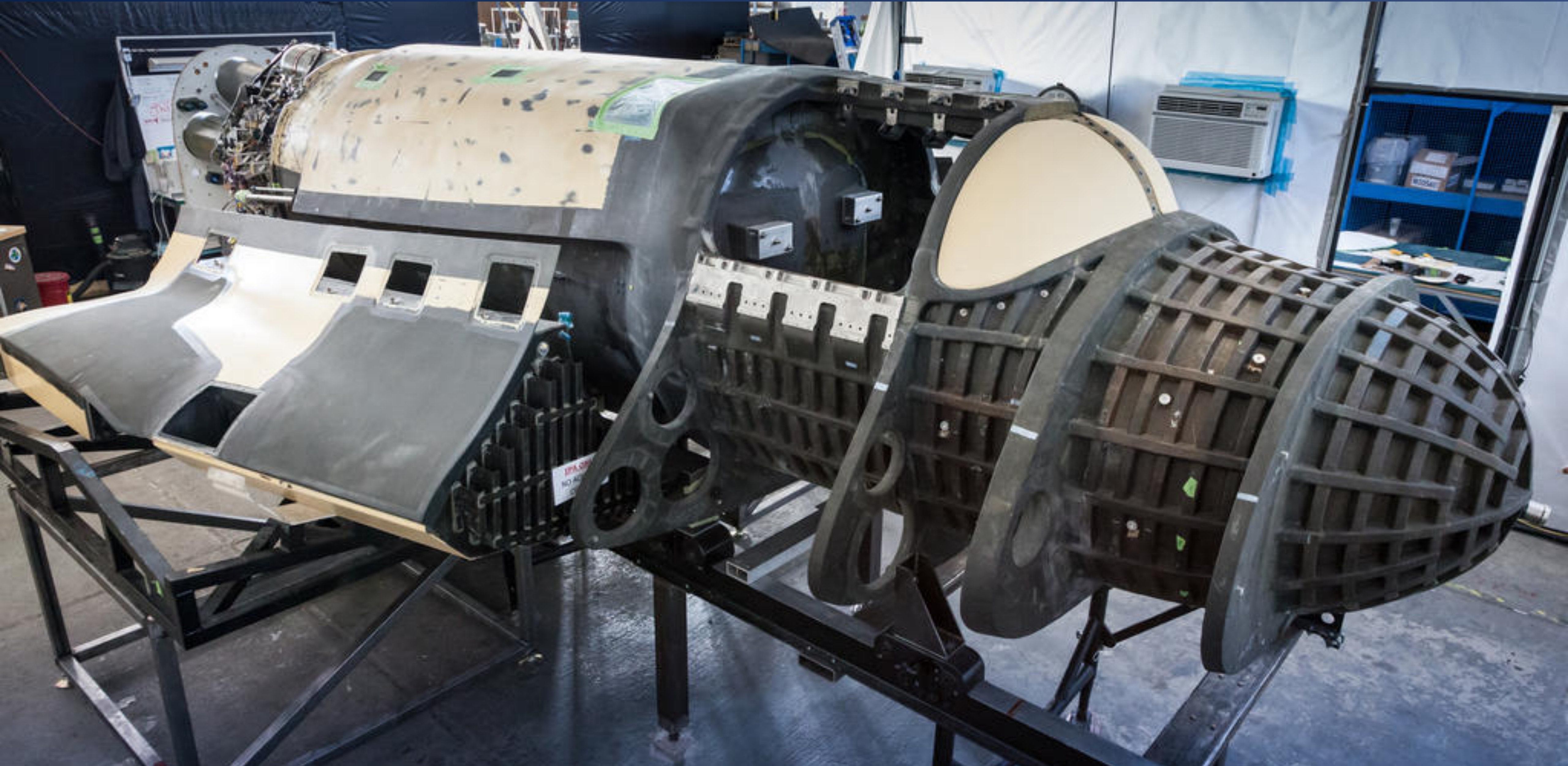


The View from Lynx





Lynx #1 Under Construction





XCOR Training





Who Killed XCOR?





A little history...





Conestoga *September 9, 1981*

First privately-financed space launch





Dennis Tito Visits ISS *April 2001*



First space tourist

 **Spaceship One** *X-Prize winner, 2004*





Spaceship Two... *announced 2005*





Spaceship Two Design





Spaceport America *New Mexico, 2011*





Spaceport America *New Mexico, 2011*





SpaceShip Two Drop Test *October 2010*





SpaceShip Two Powered Flight *April 2013*





Richard Branson in Space *12 July 2021*





Spaceship Two *12 July 2021*



Image courtesy of Virgin Galactic



Blue Origin 20 July 2021





Blue Origin 20 July 2021





Blue Origin 20 July 2021





Blue Origin 20 July 2021





Blue Origin *20 July 2021*



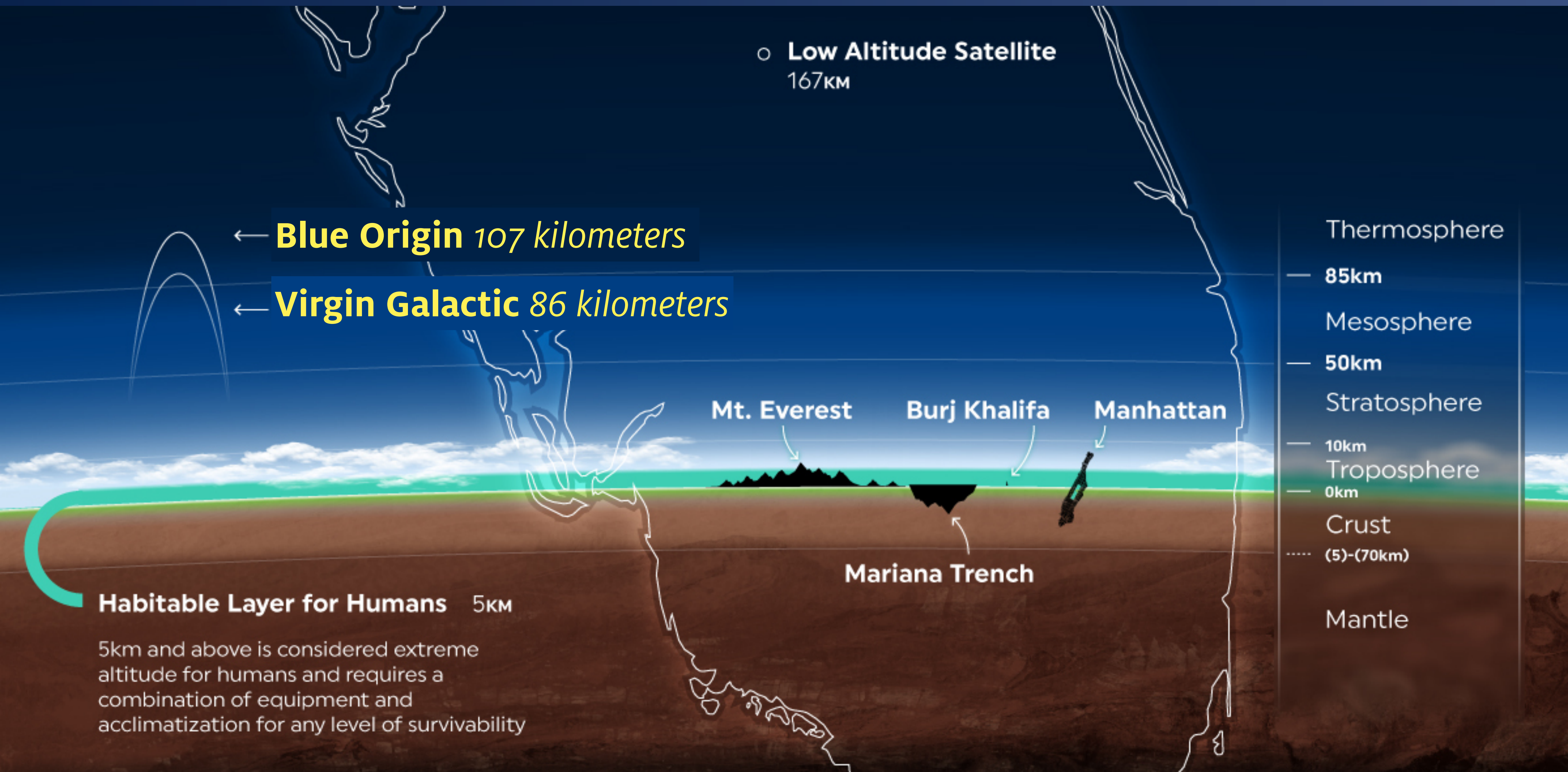


After 17 Years, a Dead Heat!





Did They Go to Space? *Or to Space** ?



← **Blue Origin** 107 kilometers

← **Virgin Galactic** 86 kilometers

○ **Low Altitude Satellite**
167km

Mt. Everest

Burj Khalifa

Manhattan

Mariana Trench

Thermosphere

85km

Mesosphere

50km

Stratosphere

10km

Troposphere

0km

Crust

(5)-(70km)

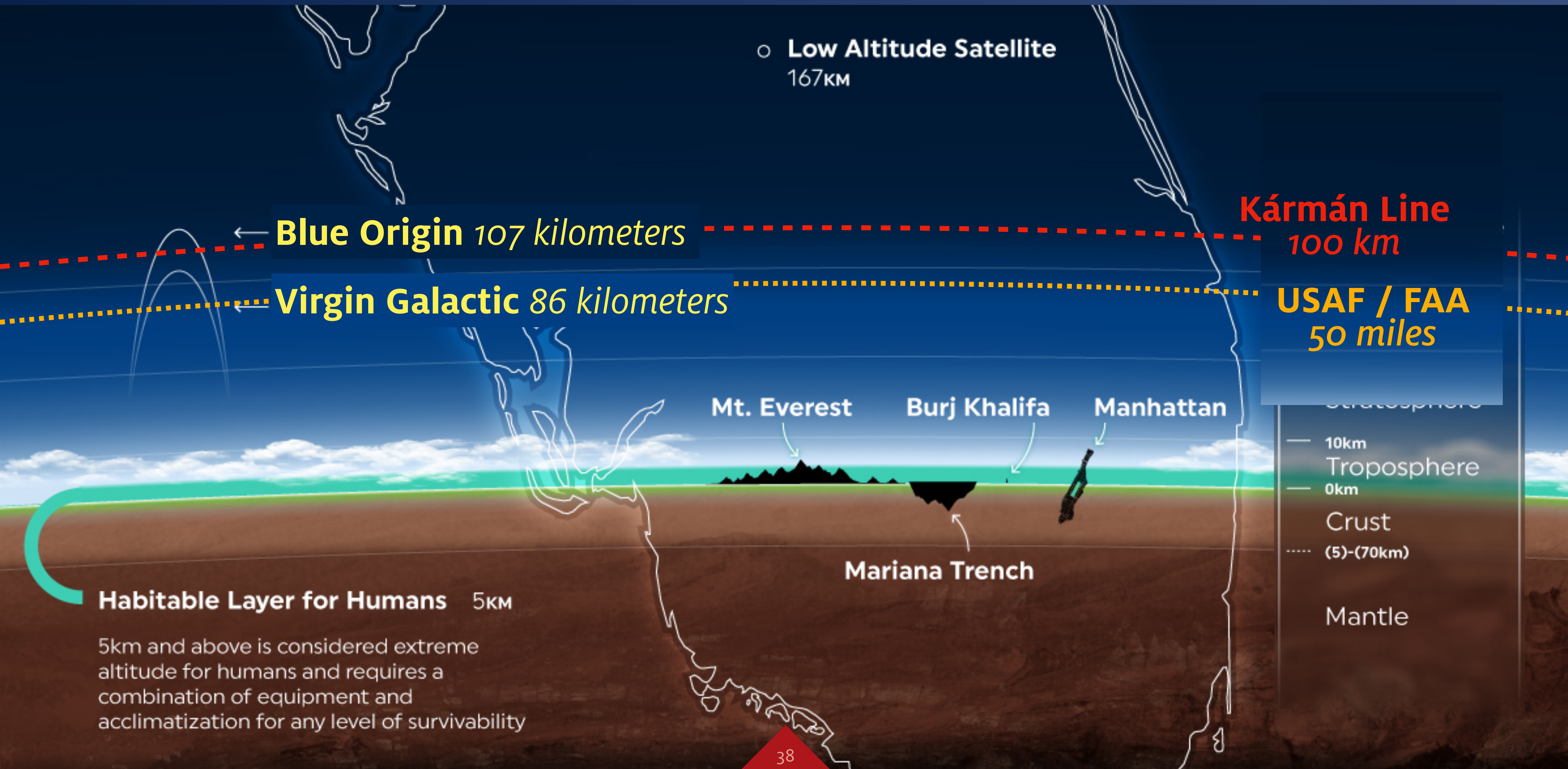
Mantle

Habitable Layer for Humans 5km

5km and above is considered extreme altitude for humans and requires a combination of equipment and acclimatization for any level of survivability

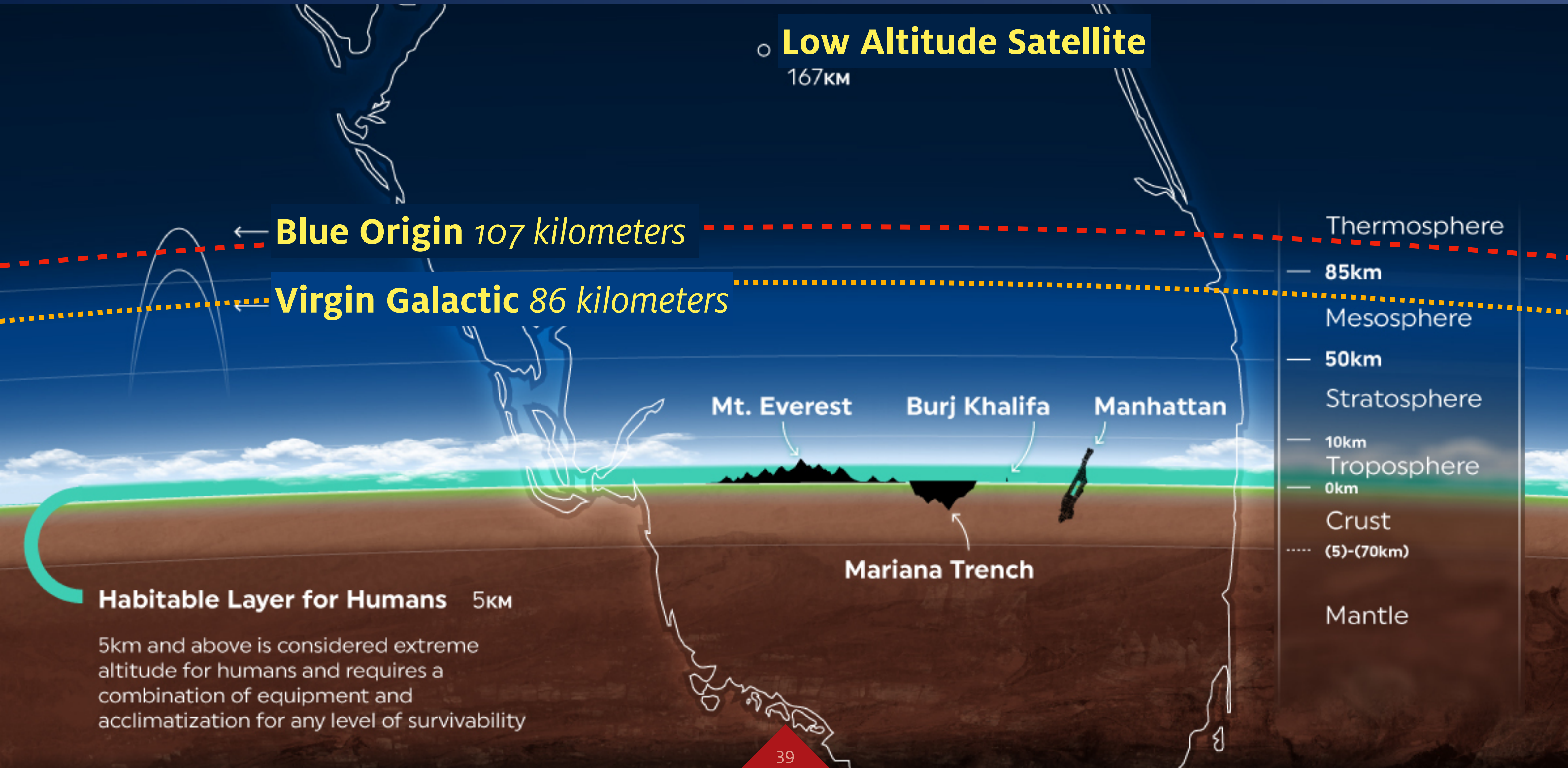


Did They Go to Space? *Or to Space** ?





Did They Go to Orbit?





Did They Go to Orbit?

○ Low Altitude Satellite
167KM

← Blue Origin 107 kilometers

← Virgin Galactic 86 kilometers

Oh, heck, no!

Only about 2% of the way there.

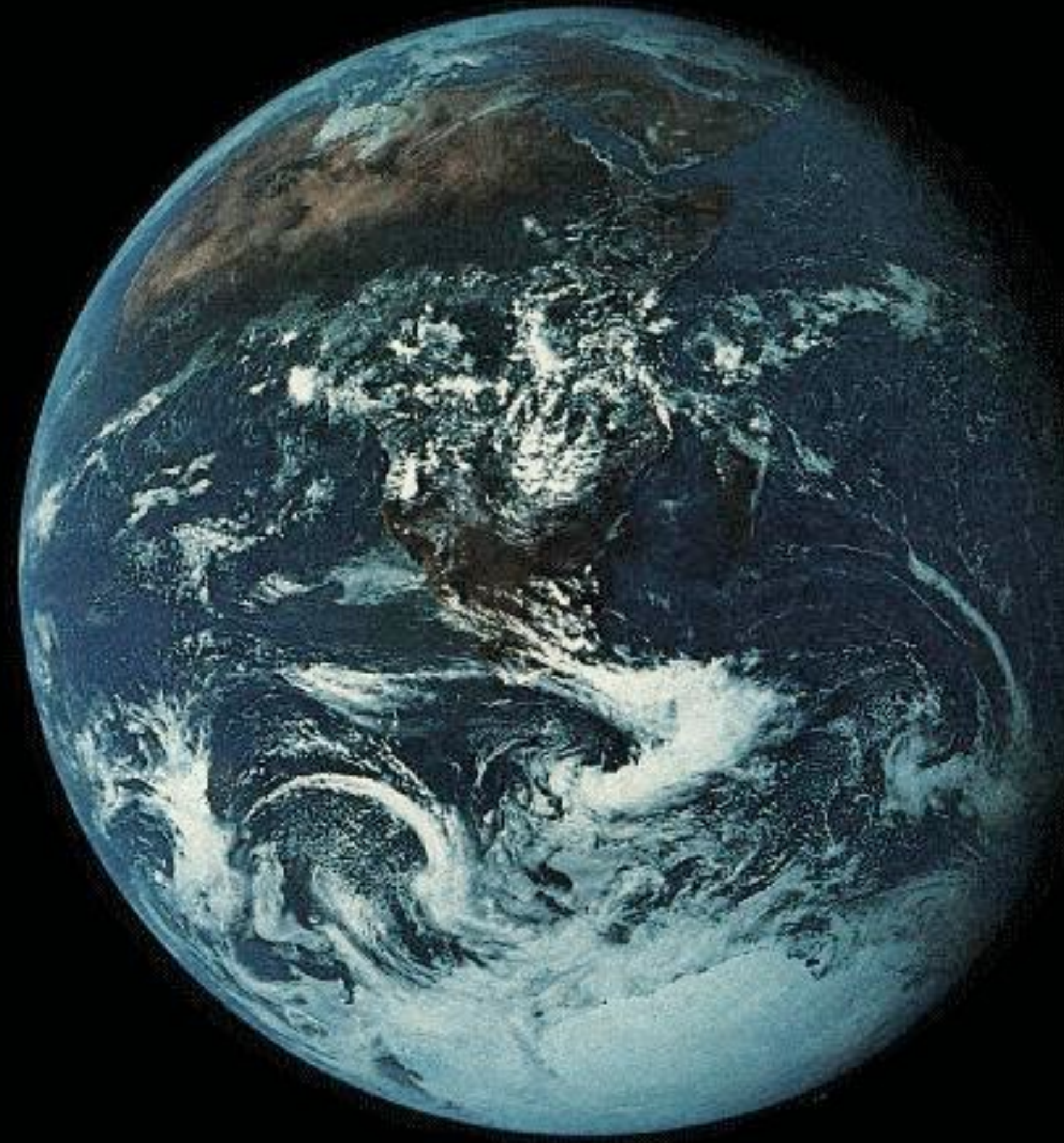
Habitable Layer for Humans 5KM

5km and above is considered extreme altitude for humans and requires a combination of equipment and acclimatization for any level of survivability

Mariana Trench

..... (5)-(70km)

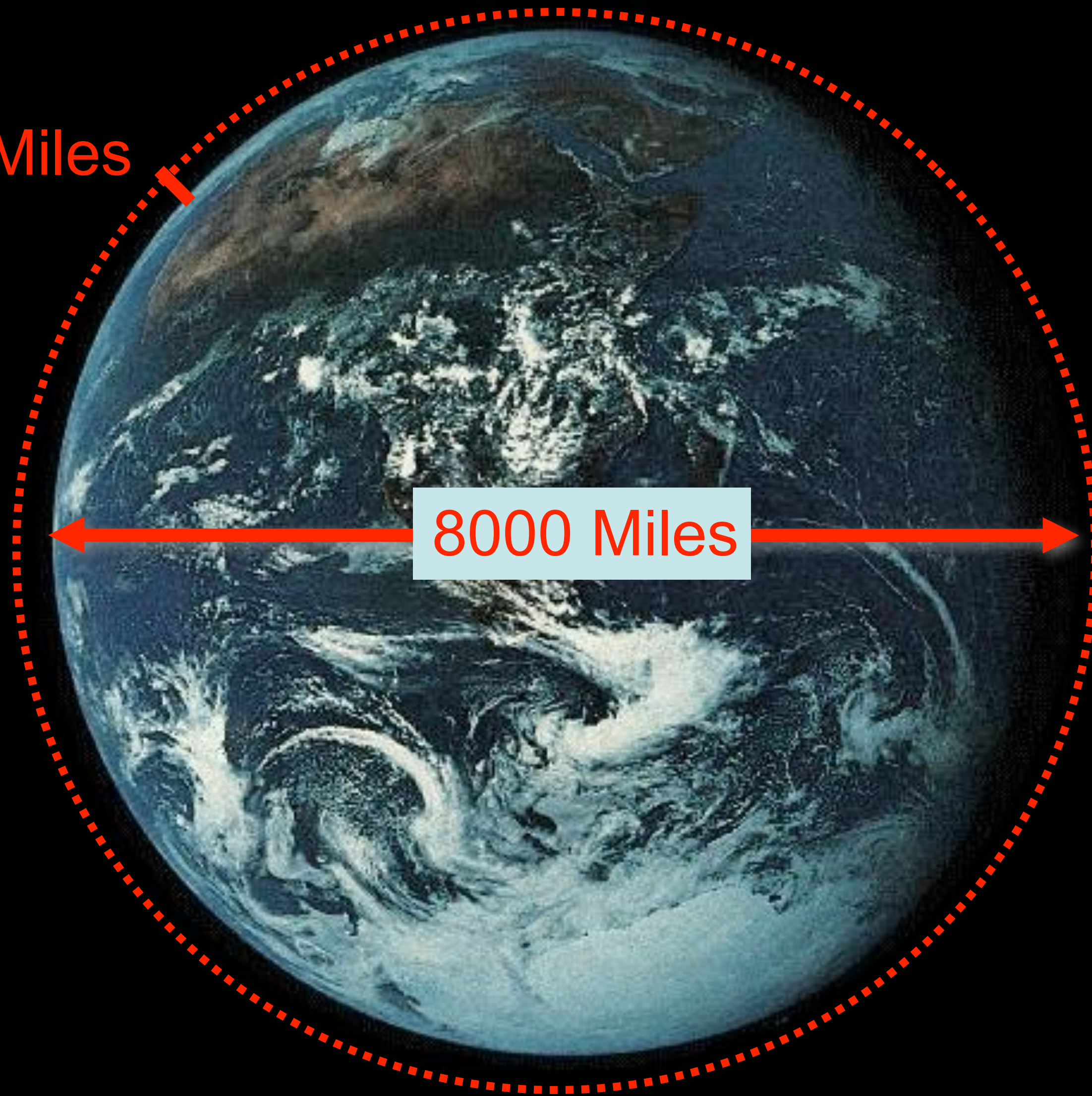
Mantle





ISS Orbit (to scale)

250 Miles



8000 Miles



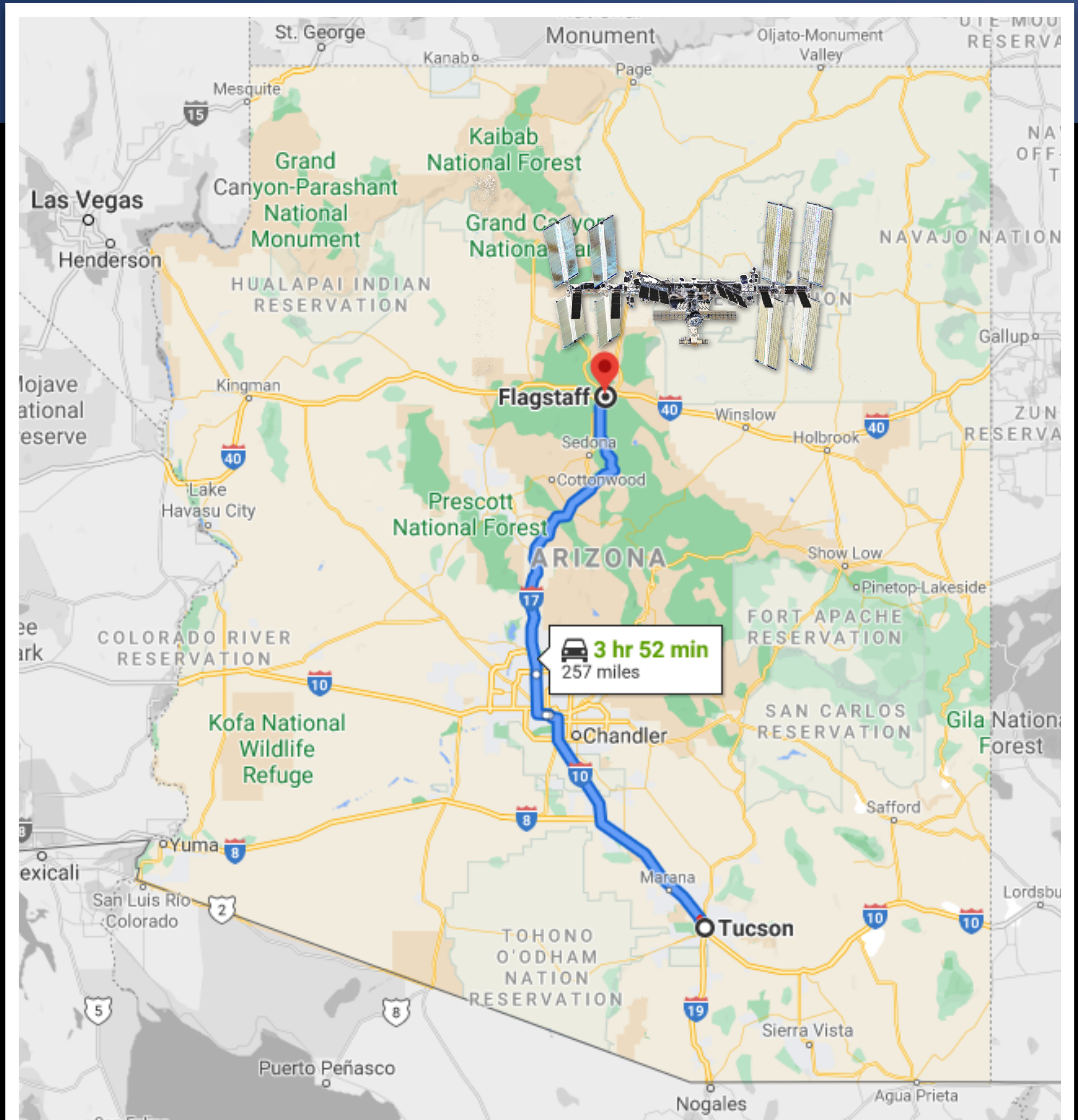
SPACE

250 Miles



250 Miles

The ISS orbit is about as far from Tucson as Flagstaff.





Altitude

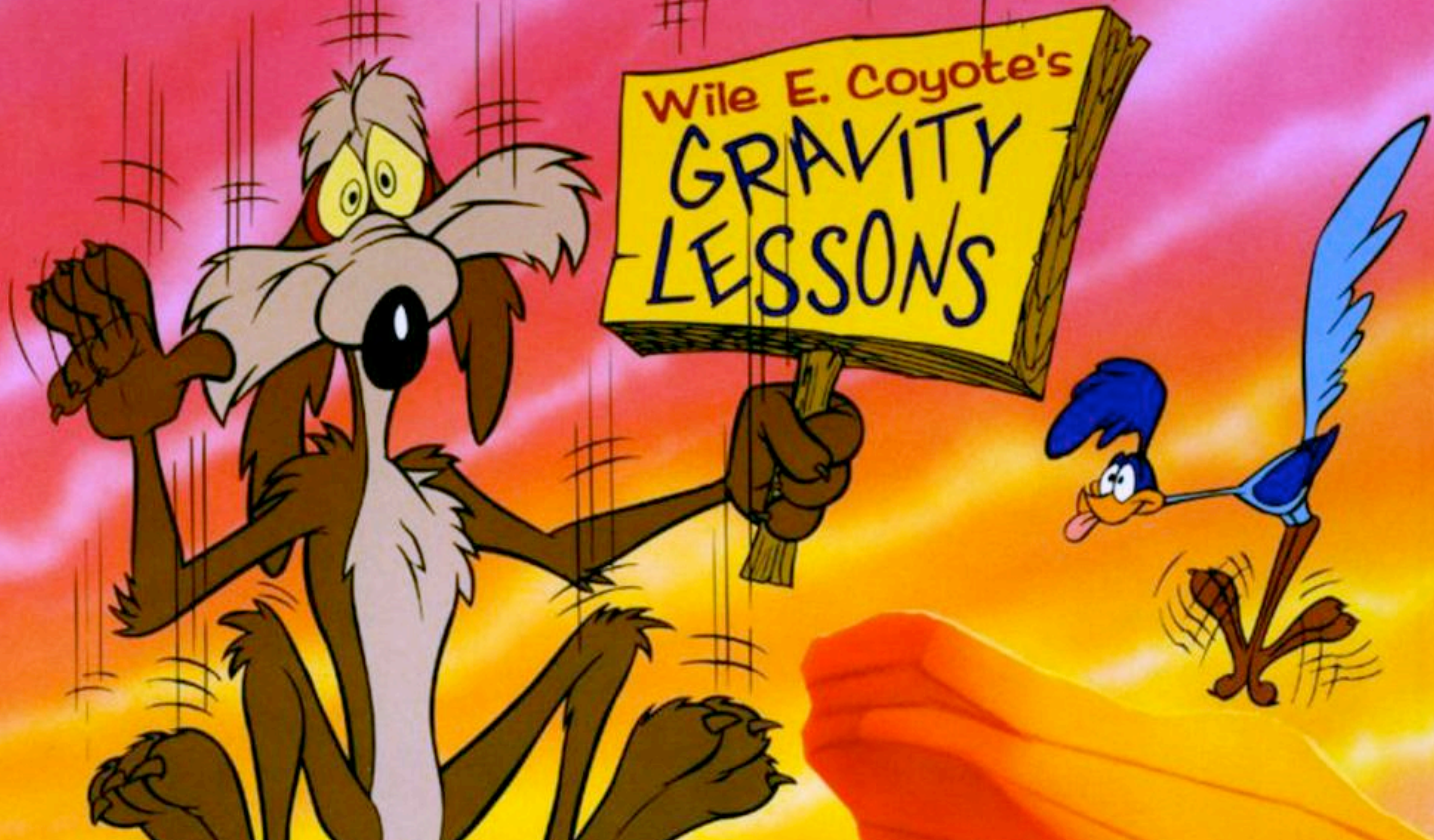


Kármán Line
100 km

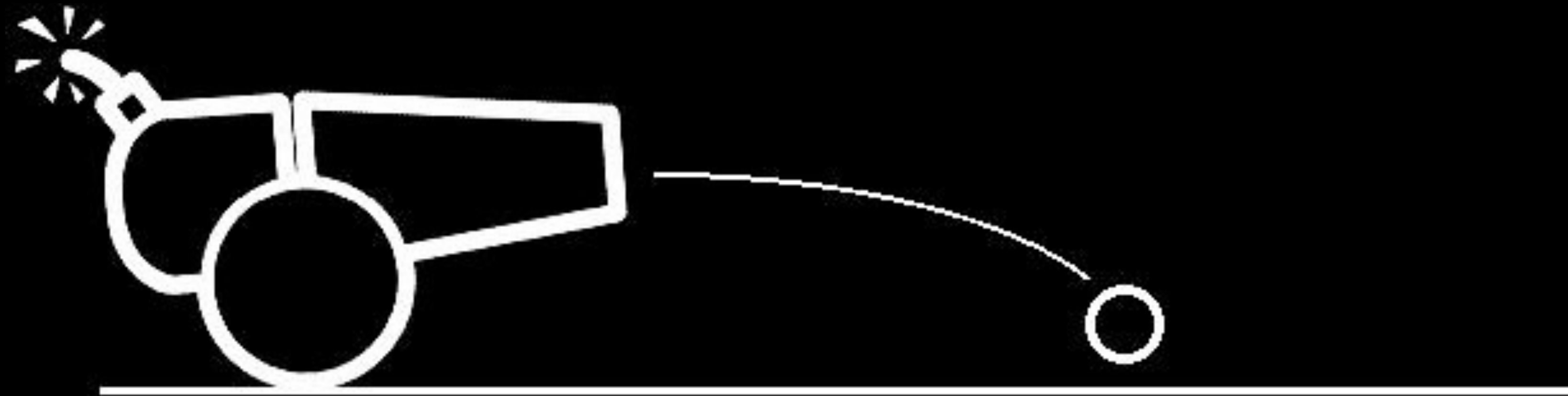


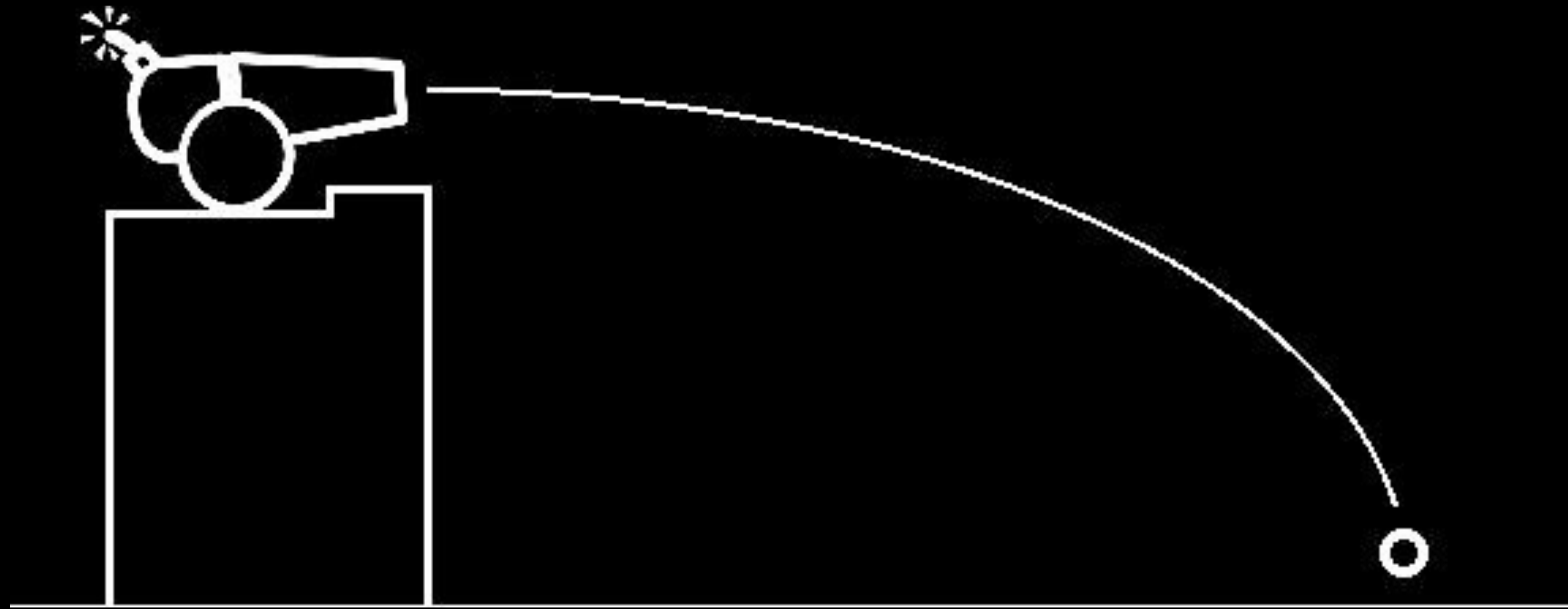
Orbital Altitude

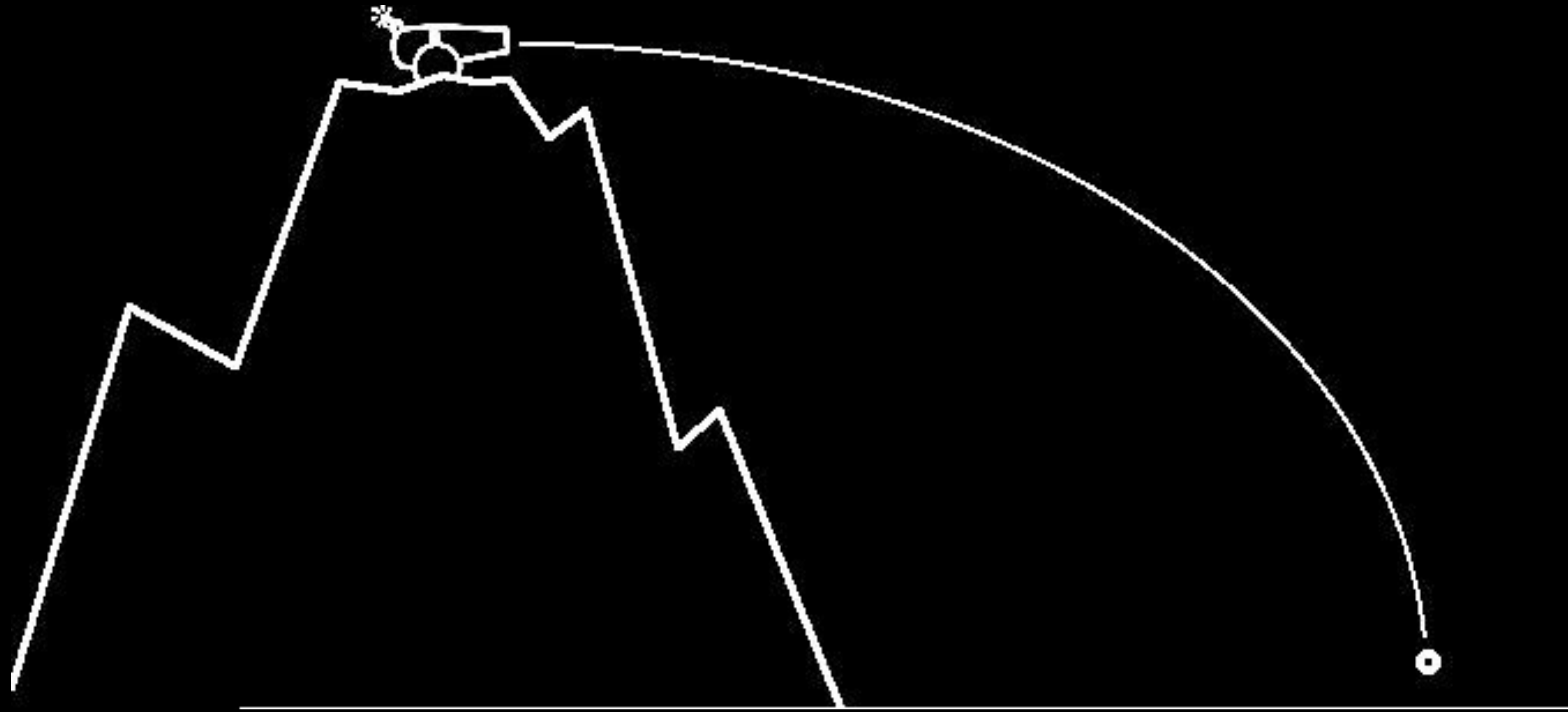




Wile E. Coyote's
**GRAVITY
LESSONS**



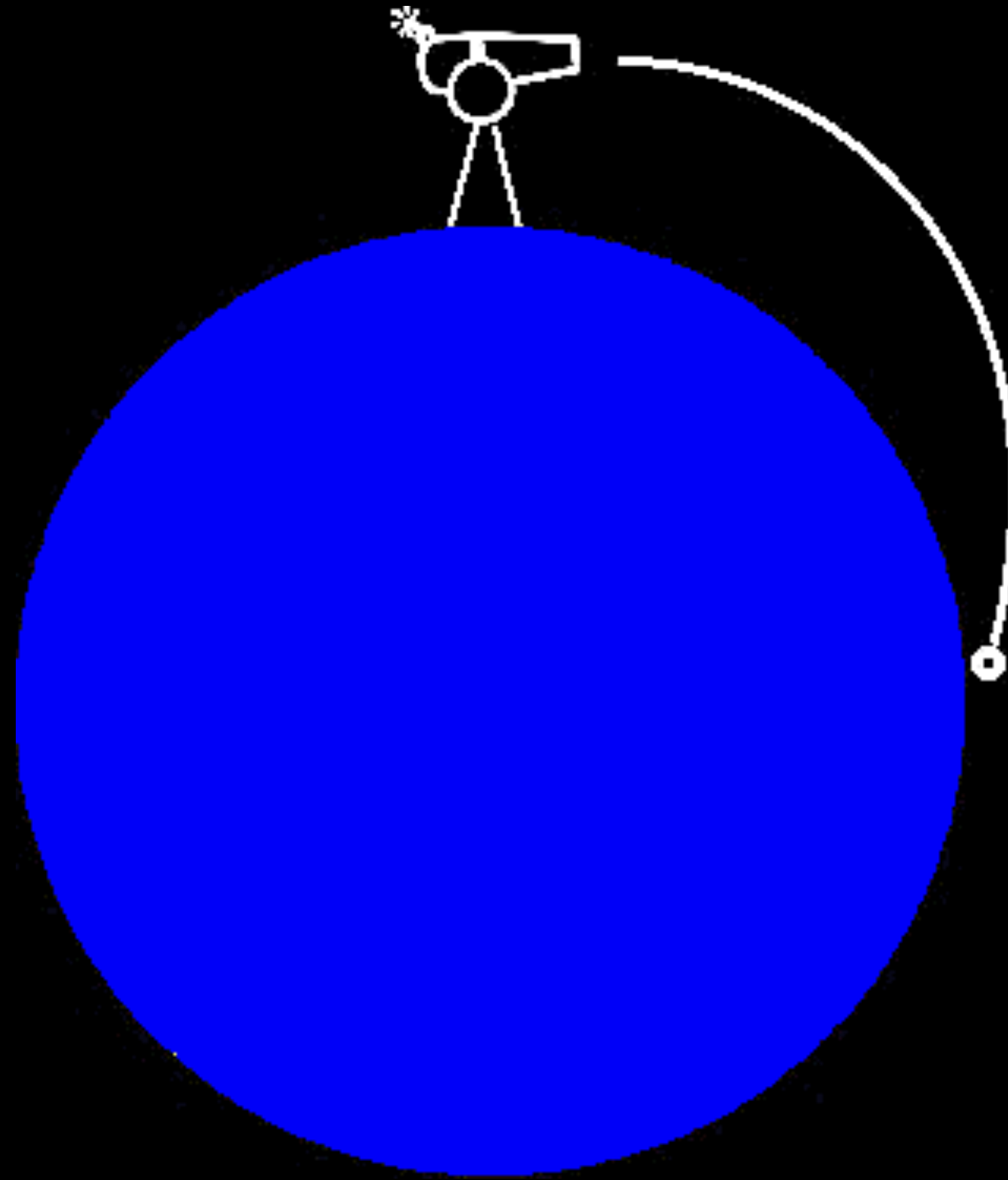


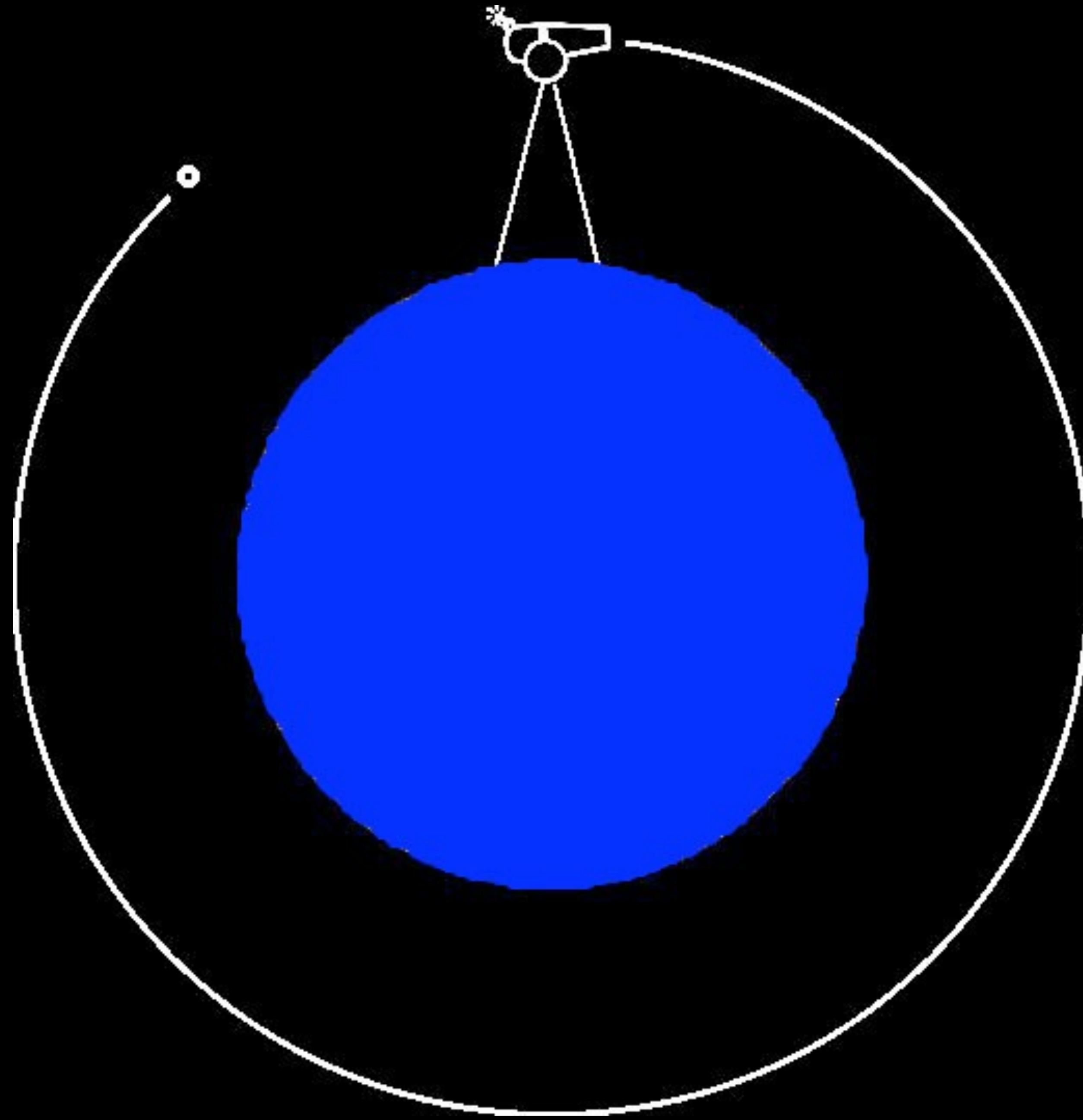


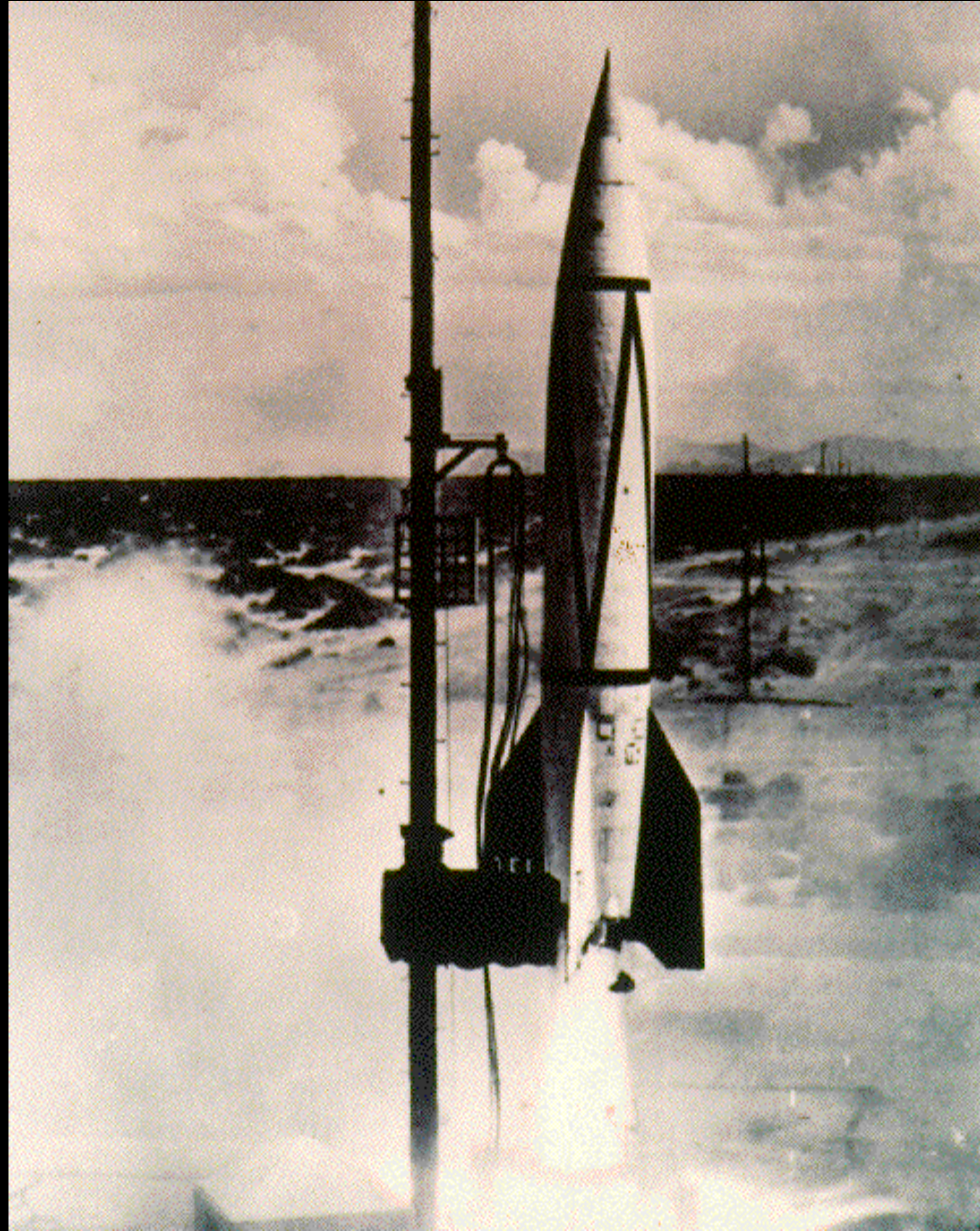


The World is not Flat!

















Rockets go Sideways





final speed \rightarrow $m v \frac{dv}{dt} = - \frac{GMm}{x^2} \frac{dx}{dt}$ $v = \frac{dx}{dt}$ (trick)

initial speed \rightarrow $\int_0^{v_f} m v dv = \int_{x_0}^{x_f} - \frac{GMm}{x^2} dx$

integrate, but stop at 1 AU - comet doesn't crash.
 don't use $x_f = 0$ (why?)
 initial location, $x_0 = 50,000$ AU

$$\frac{1}{2} m v_f^2 = \frac{GMm}{x_f} - \frac{GMm}{x_0}$$

$$\frac{1}{2} m v(x)^2 = \frac{GMm}{x} - \frac{GMm}{x_0}$$

The choice of x_f is arbitrary!

First integral of the motion:

$$\frac{dx}{dt} = \pm \sqrt{2GM \left(\frac{1}{x} - \frac{1}{x_0} \right)}$$

'-' sign is correct in our case!

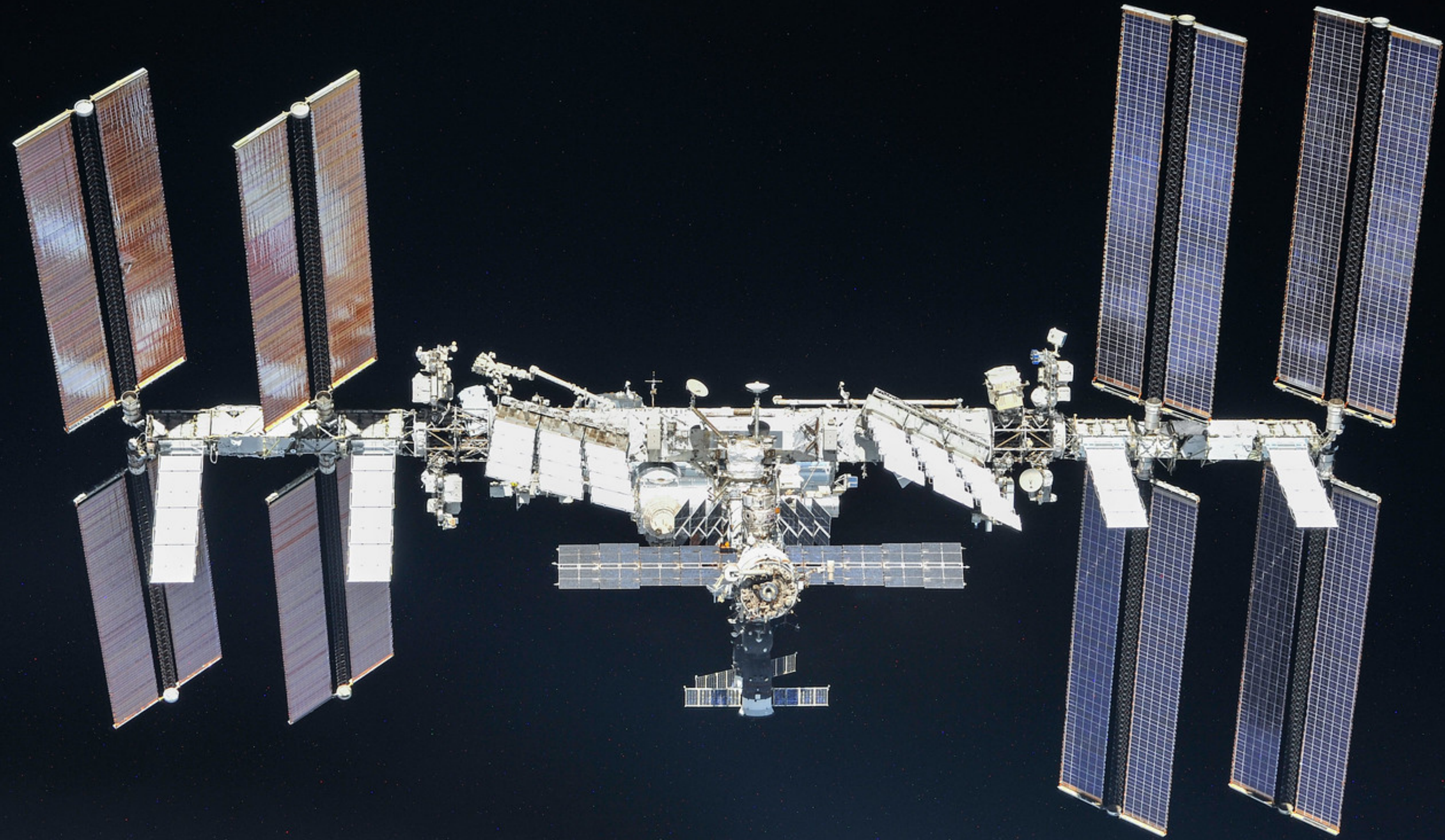
How fast is it for $x_f = 1$ AU?
 m drops out
 $M \approx 2 \times 10^{30}$ kg
 $v_f \approx 42$ km/s

Calculate the time it took the comet to reach $x_f = 1$ AU by isolating dt and integrating:

$$t_f = \int_0^{t_f} dt = - \int_{x_0}^{x_f} \frac{dx}{\sqrt{2GM \left(\frac{1}{x} - \frac{1}{x_0} \right)}} = \frac{2}{3} \frac{1}{\sqrt{2GM}} (x_0^{3/2} - x_f^{3/2})$$

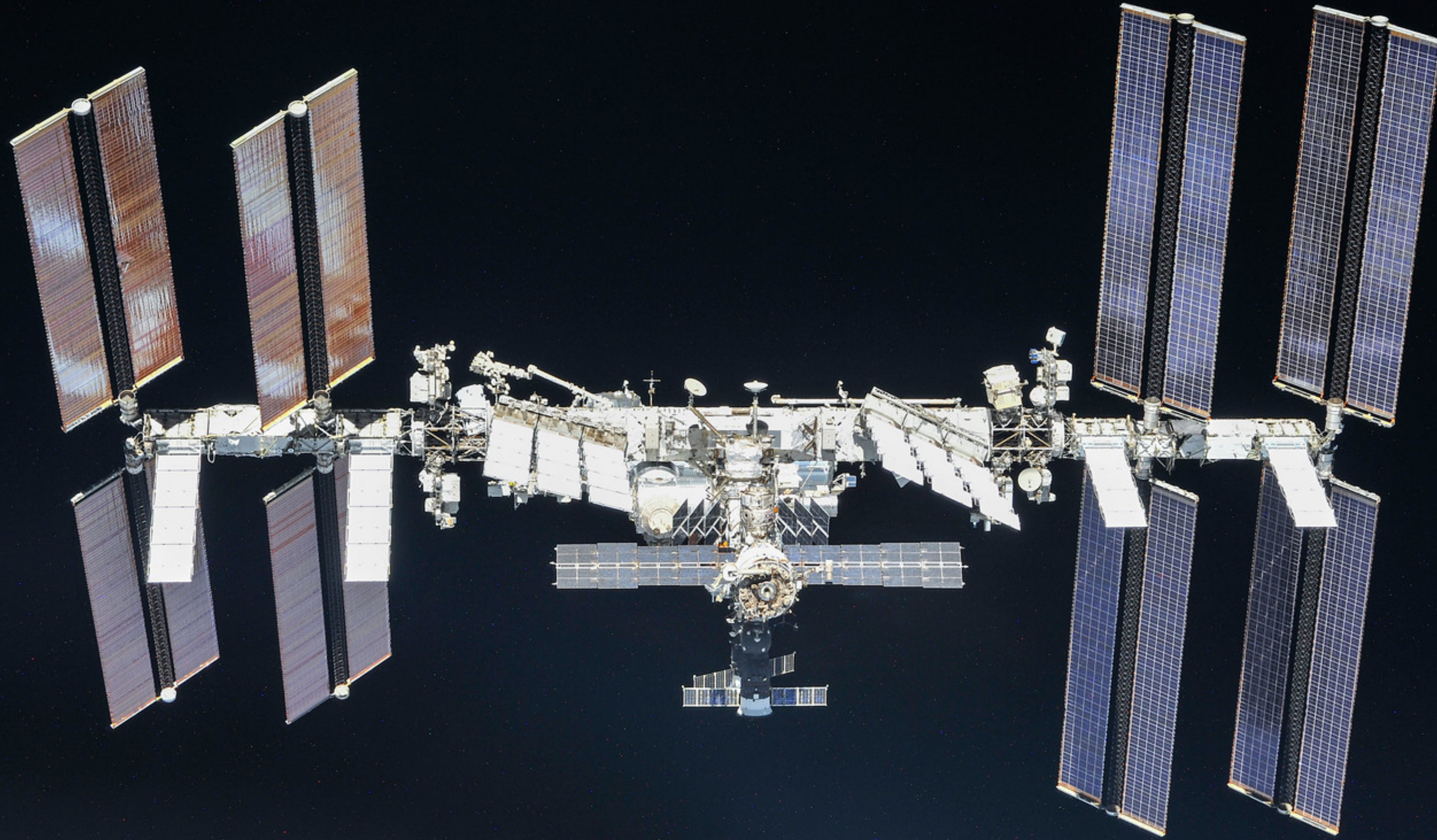
$$t_f \approx \frac{2}{3} \frac{1}{\sqrt{2GM}} x_0^{3/2} \approx 4 \times 10^{13} \text{ s} \approx 1.3 \times 10^6 \text{ years}$$

negligible? No, choose $U(x_0) = 0$



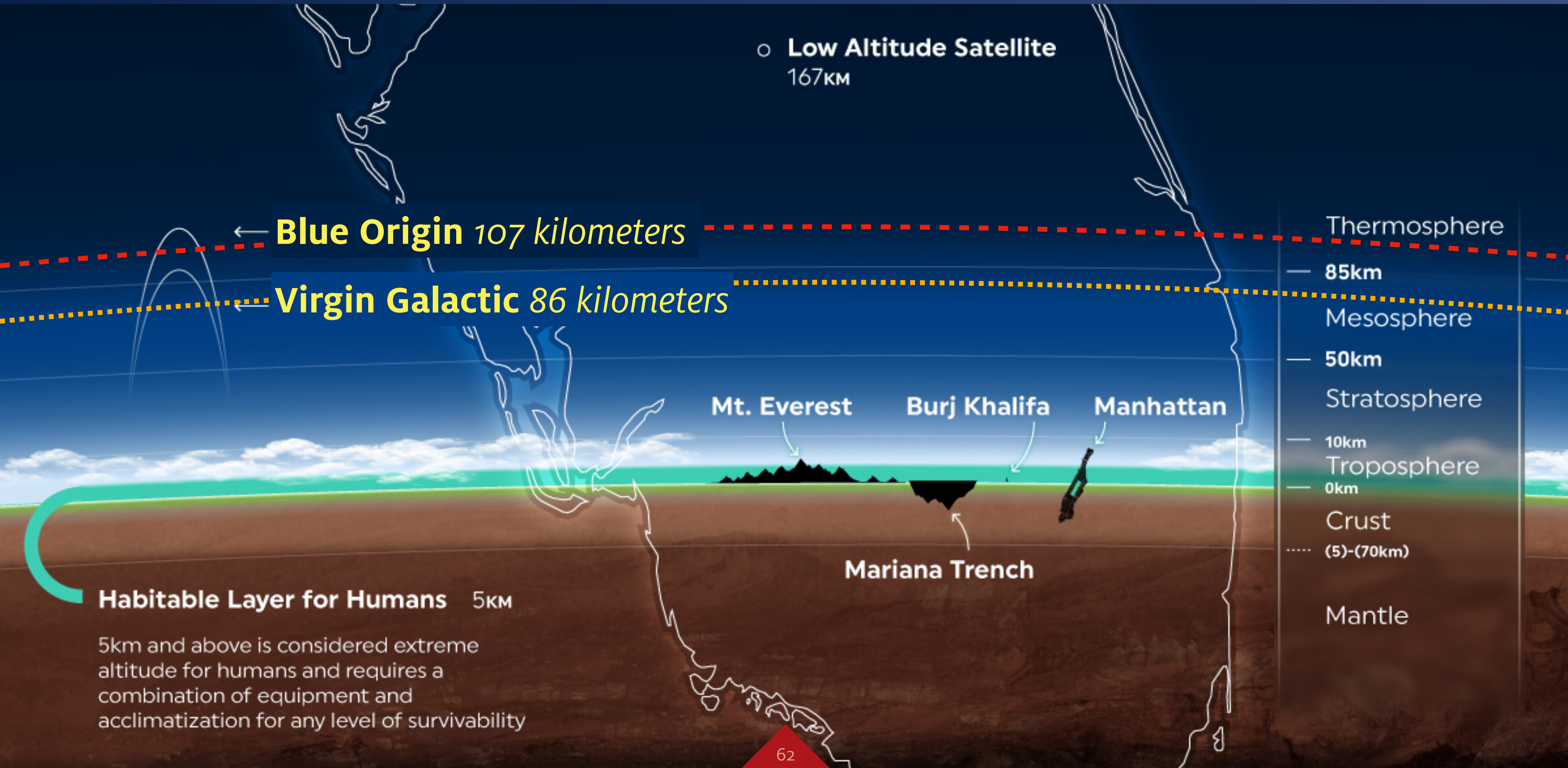


Orbiting at 17,500 mph



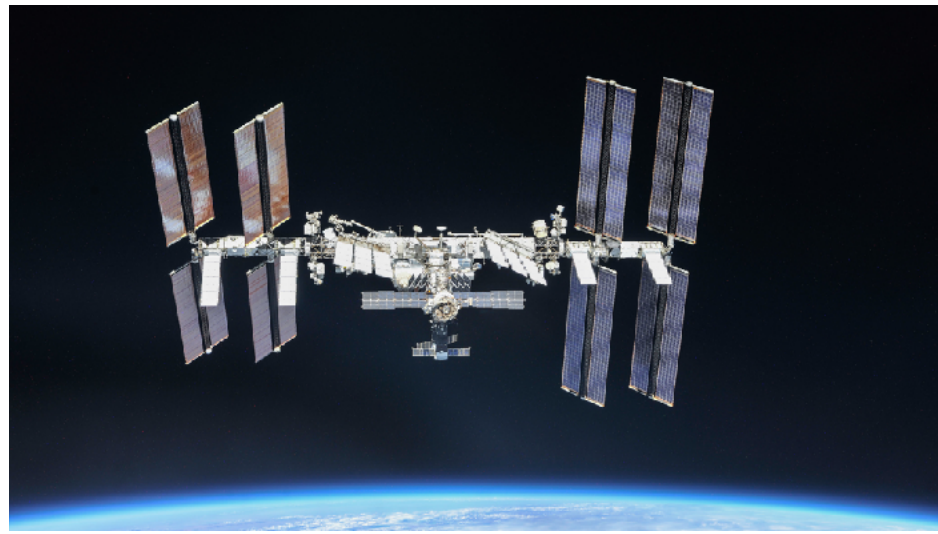


Did They Go to Orbit?





Comparison of Velocities



International Space Station

Orbital Velocity: 17,500 mph



**Alan Shepard,
suborbital flight, 1961**

Suborbital max velocity
5,134 mph



SpaceShip Two

Only ~14% of orbital velocity

Suborbital max velocity:
2,485 mph



Blue Origin "New Shepard"

Suborbital max velocity:
2,217 mph



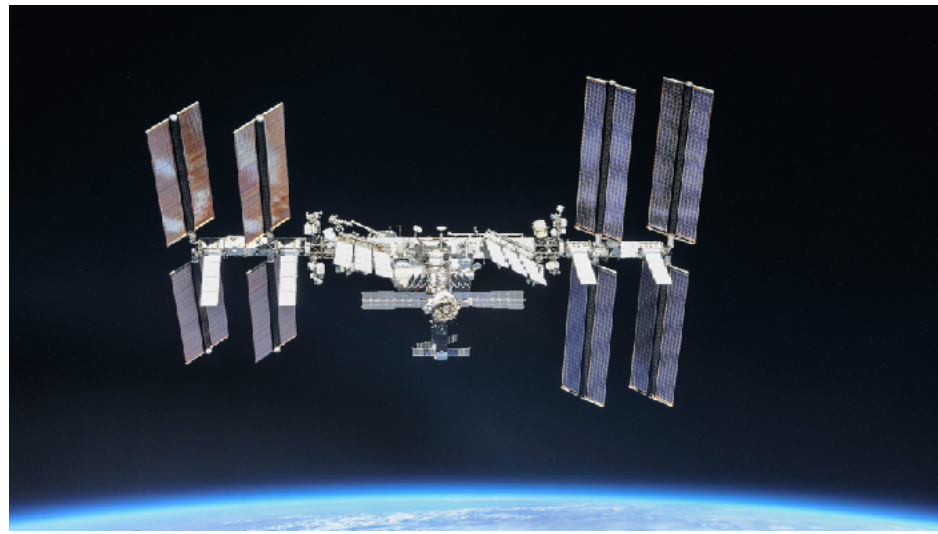
But... what about Kinetic Energy?

$$KE = \frac{1}{2} m v^2$$

Kinetic energy grows as the *square* of the velocity!



Comparison of Kinetic Energies

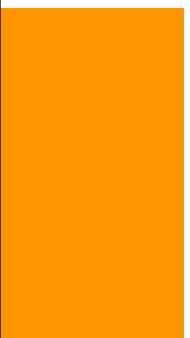


International Space Station

KE: 28.9 gigajoules/kilogram



Alan Shepard,
suborbital flight, 1961



2.6 GJ/kg



SpaceShip Two

Only ~2% of orbital *energy*



0.6 GJ/kg



Blue Origin "New Shepard"

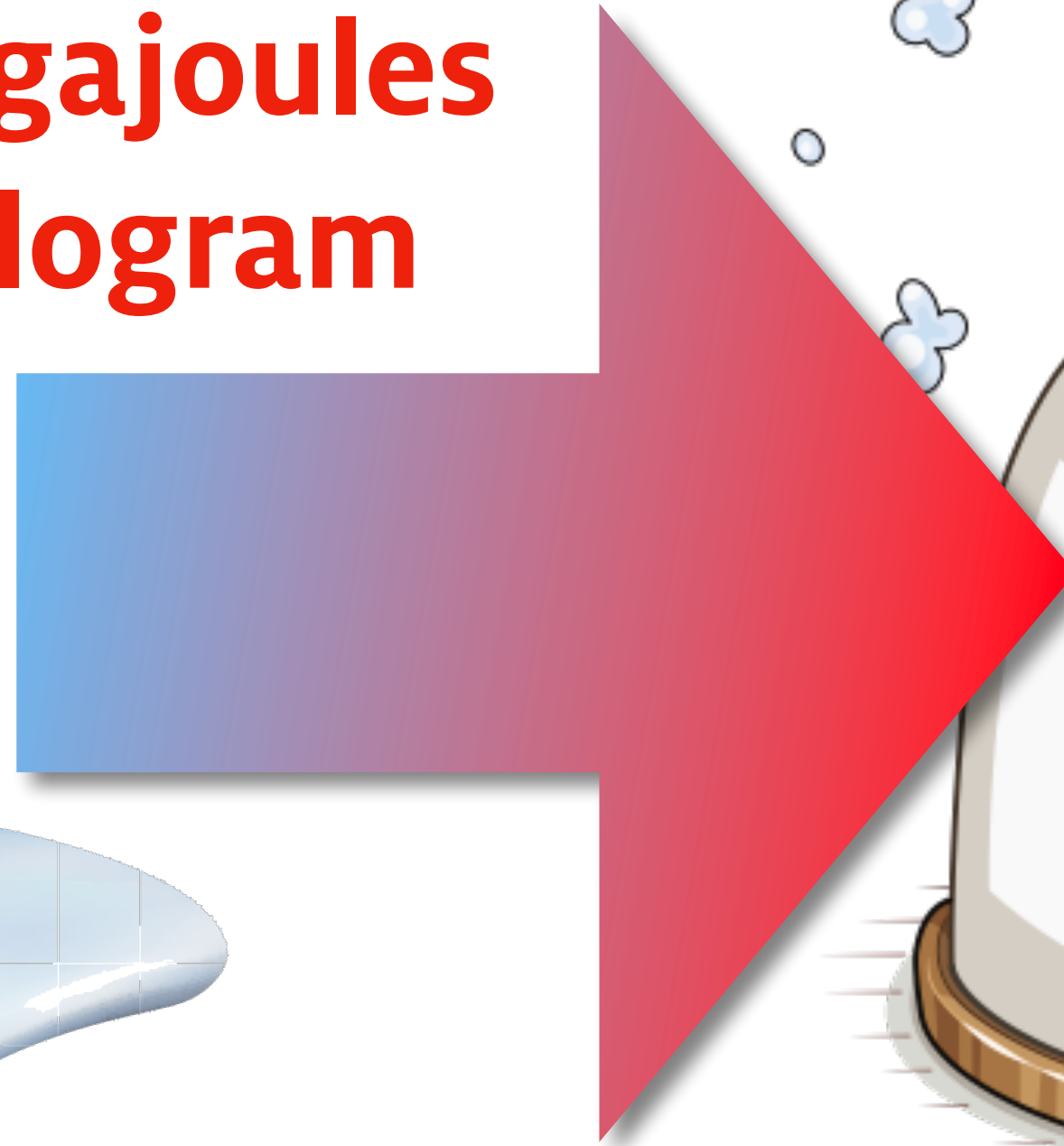


0.5 GJ/kg



Imagine Converting Ice to Steam...

**6.8 megajoules
per kilogram**



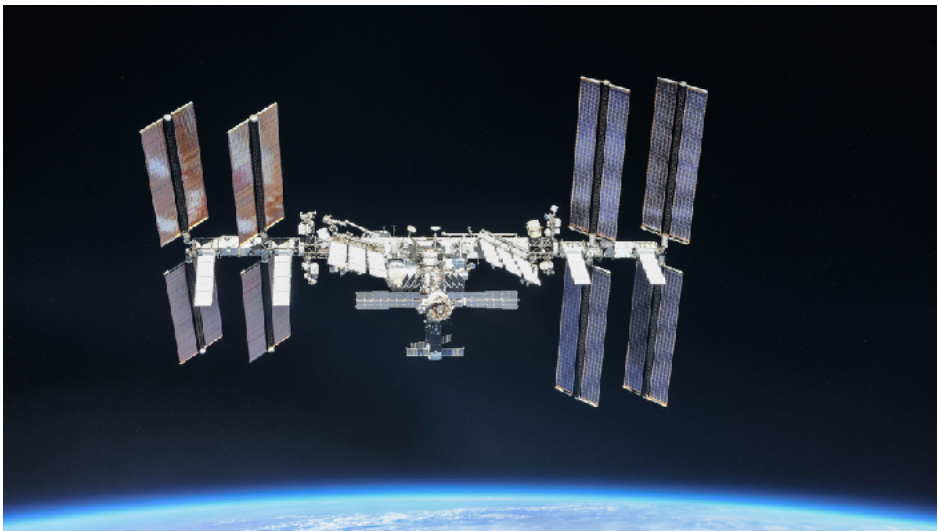


Now Imagine Tank Cars Full of Ice...





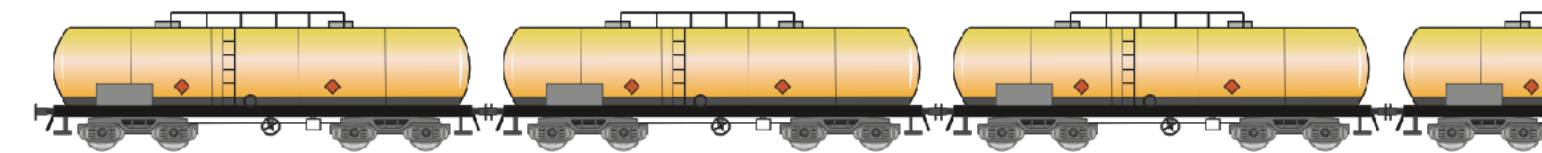
KE = How Much Ice to Steam?



International Space Station



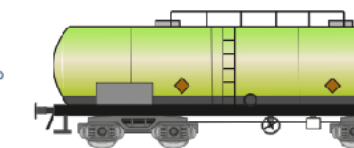
Alan Shepard,
suborbital flight, 1961



102,000
gallons



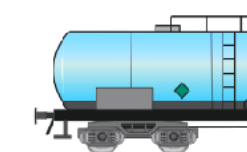
SpaceShip Two



Equivalent of converting
24,000 gallons of ice to steam



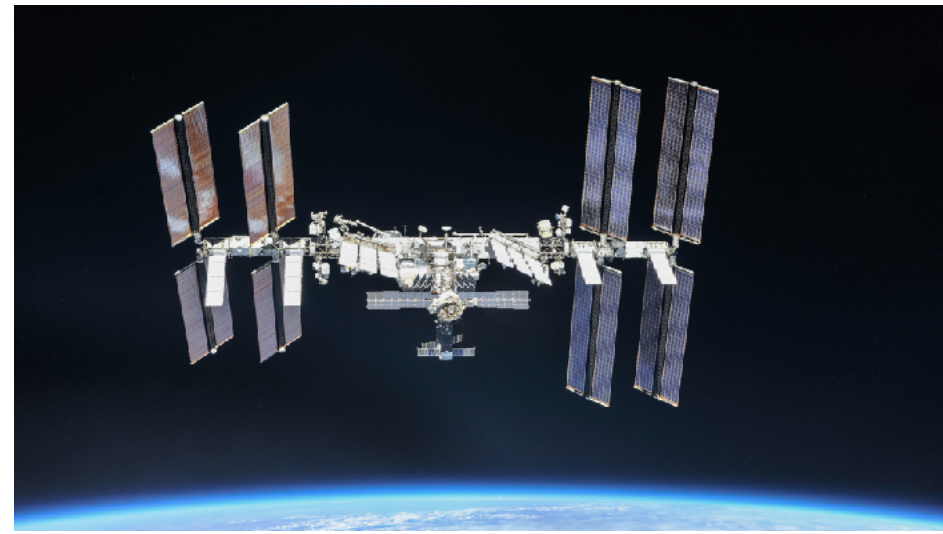
Blue Origin "New Shepard"



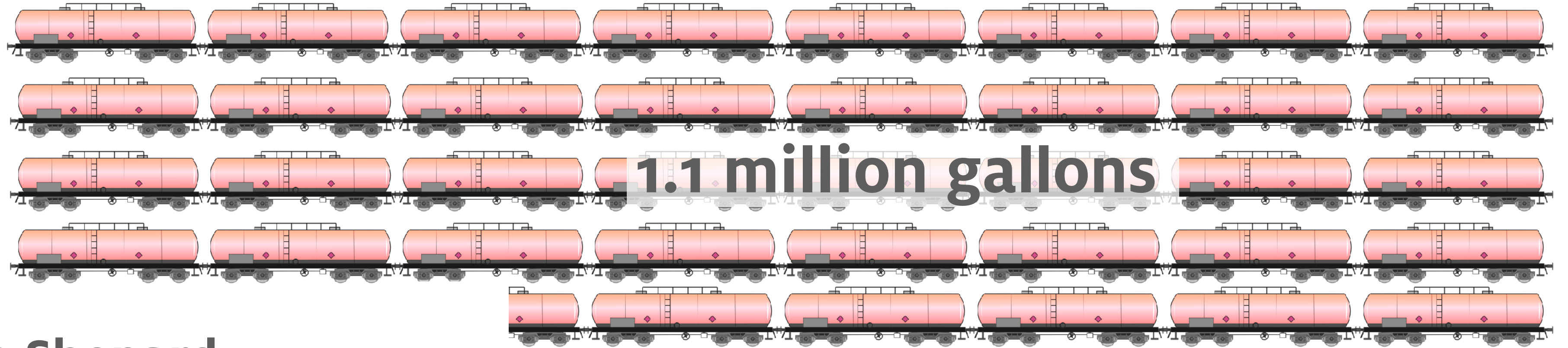
19,000 gallons



KE = How Much Ice to Steam?

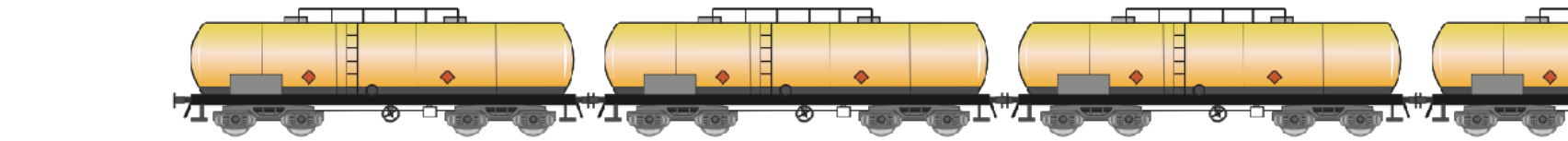


ISS



1.1 million gallons

Alan Shepard,
suborbital flight, 1961



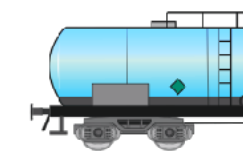
102,000
gallons

Spaceship Two



Equivalent of converting
24,000 gallons of ice to steam

Blue Origin "New Shepard"



19,000 gallons





Are We There Yet?





Inspiration 4 ...*Launching Tomorrow!*





Inspiration 4



Dr. Sian Proctor



Hayley Arceneaux



Jared Isaacman



Chris Sembroski



Inspiration 4





DearMoon





ARIZONA FORGE



Thank You!

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