ARIZONA FORGE

Space Tourism

Stephen Fleming

Executive in Residence

@stephenfleming

ARIZONA Space Business Roundtable

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:

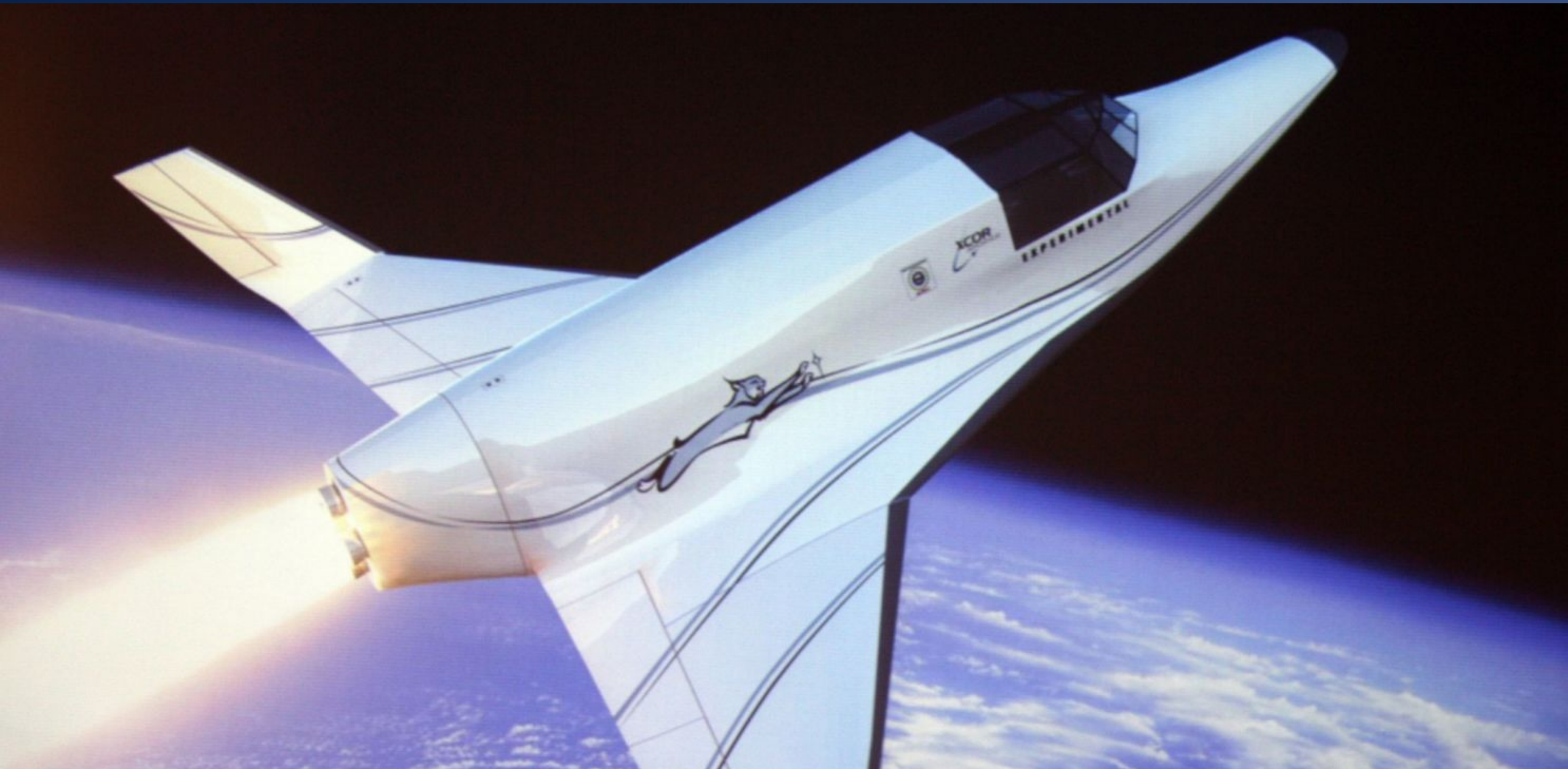
- *18 investments as lead investor*
- *12 profitable exits (including 4 IPOs, one $650M acquisition)*
- *47% annualized cash-on-cash IRR*

15 years corporate operations:

- *AT&T Bell Labs*
- *Nortel Networks*
- *LICOM (venture-backed telecom equipment startup)*

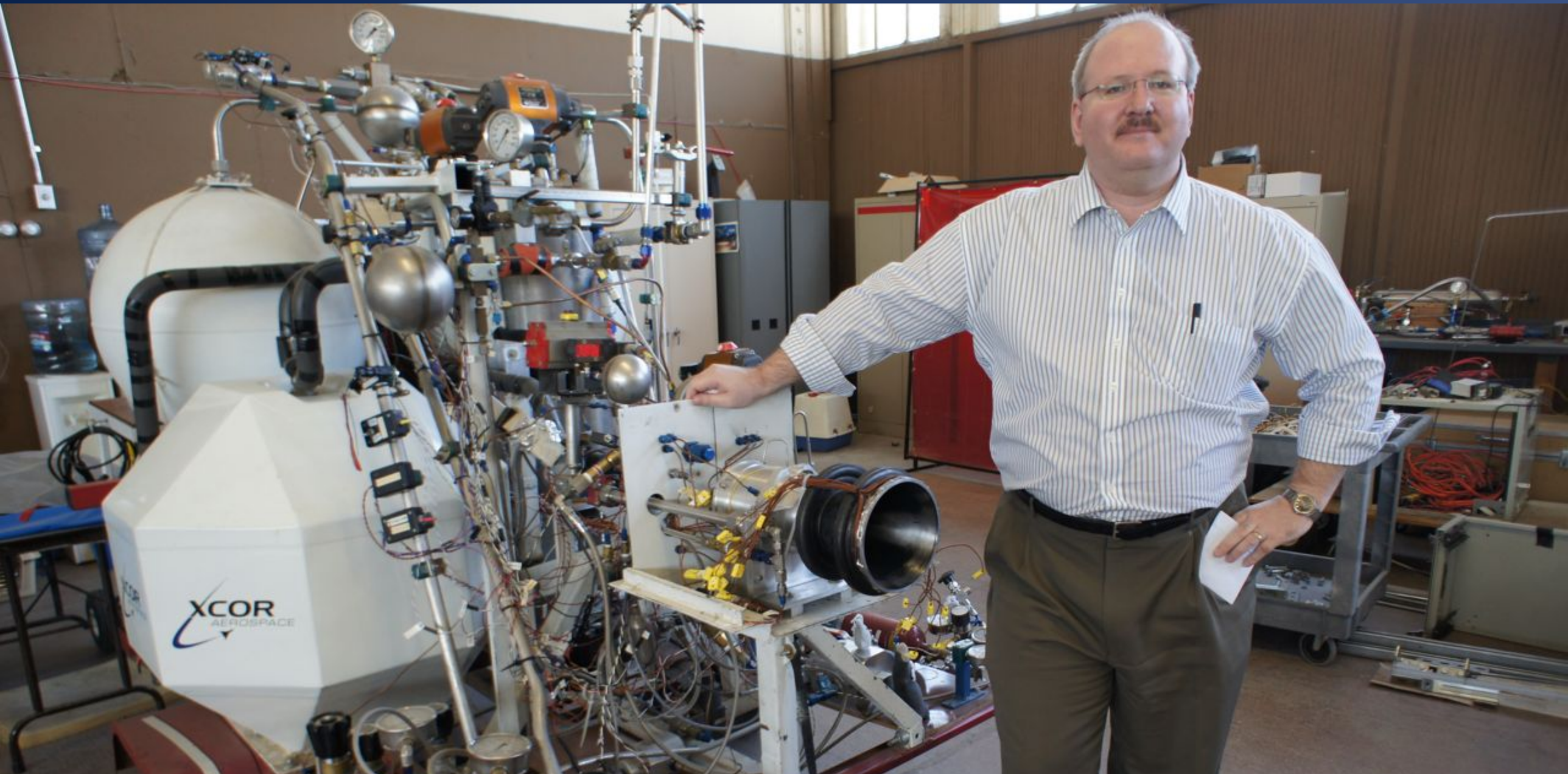
BS, Physics, Georgia Tech *(Highest Honors)*

XCOR Aerospace



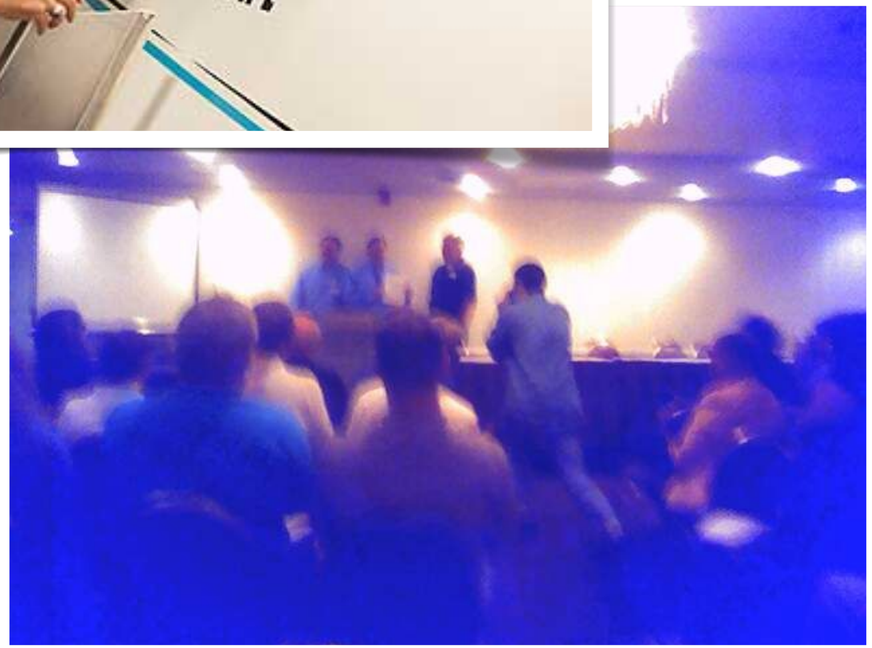
XCOR EZ-Rocket *2001*

Liquid-Fueled Engine Development



XCOR Rocket Racer *June 2008*

XCOR Development

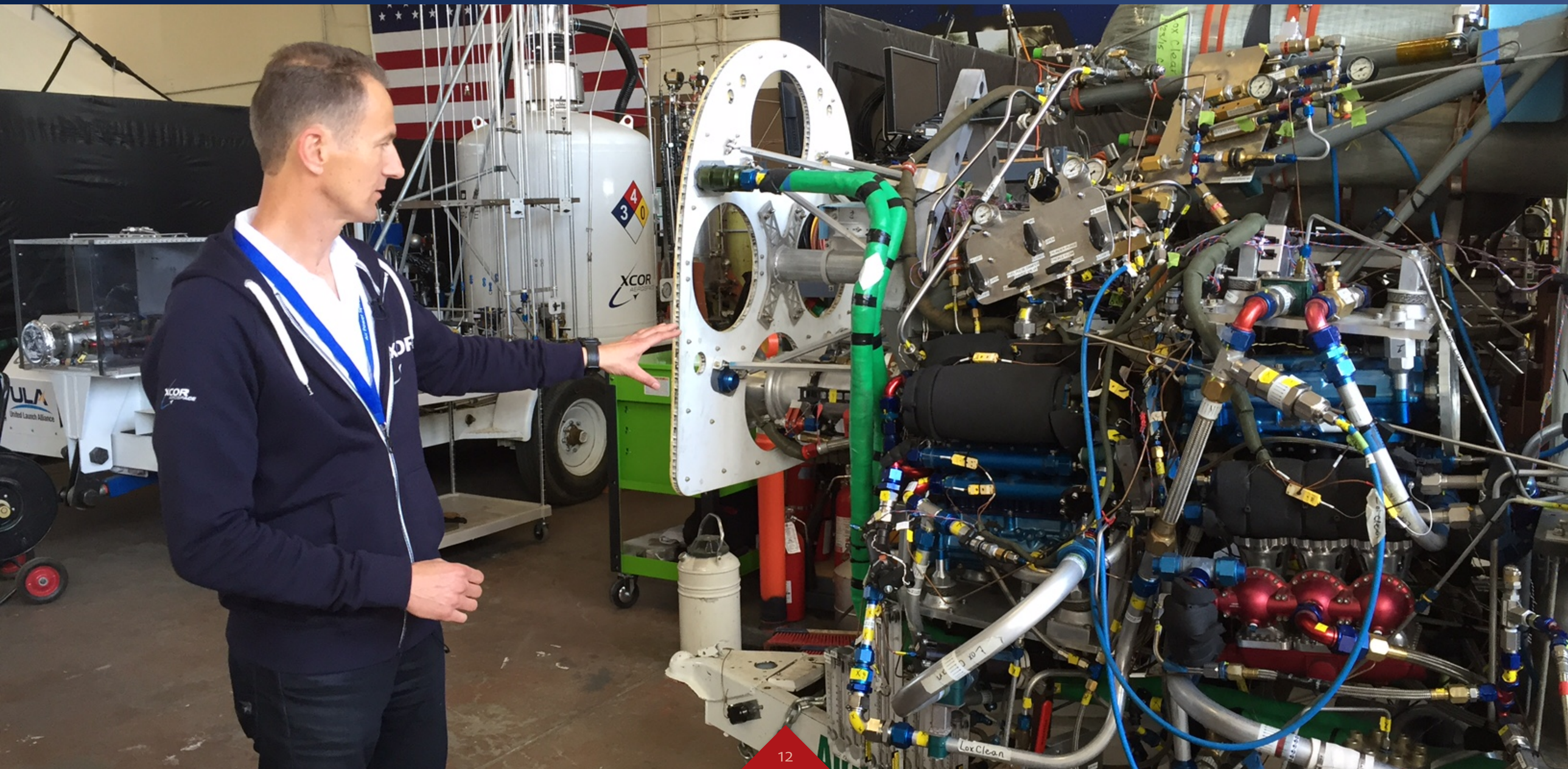


XCOR LOX-Methane Engine Development

XCOR Development

XCOR Component Testing

Rocket Plumbing

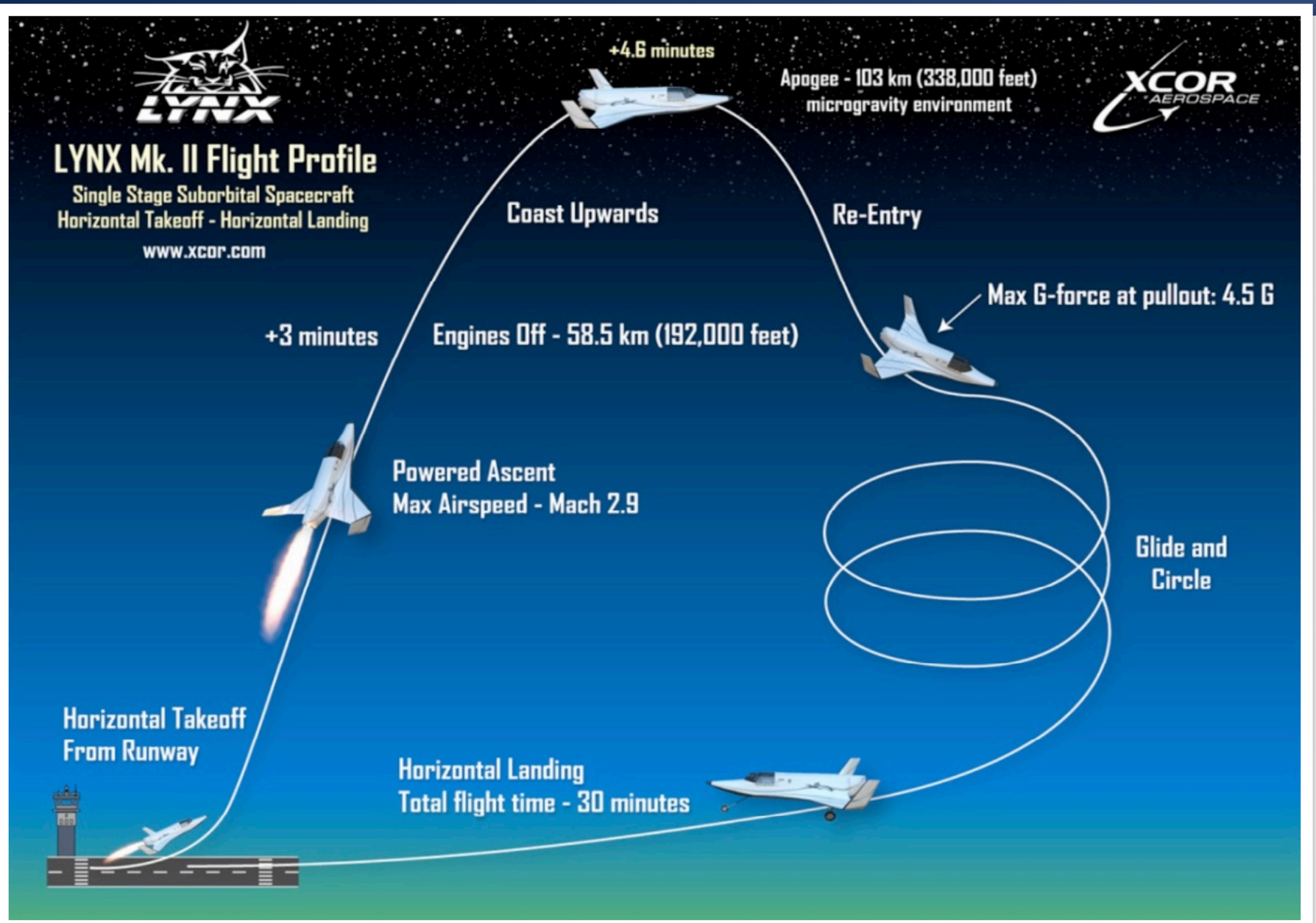


XCOR Flight Operations

Flight Operations

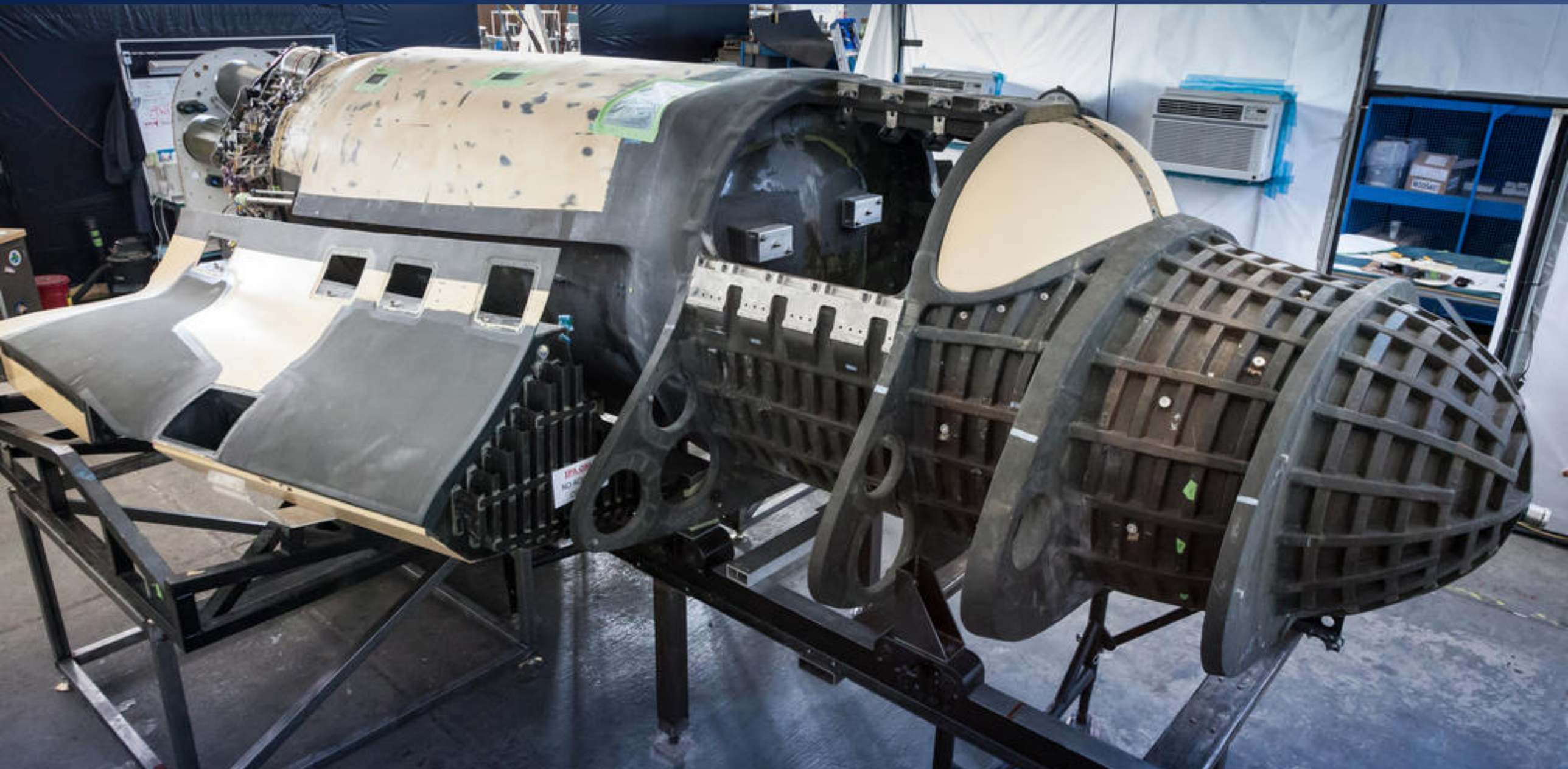
- Aircraft-like operations from any airport with a 7,000-foot (2,100 m) runway and appropriate airspace
- Fast turnaround
- Low maintenance: 2 hour engine runtime overhaul intervals
- Up to 4 sorties per day
- Weather/seasonal constraints: winds

XCOR Lynx Flight Profile



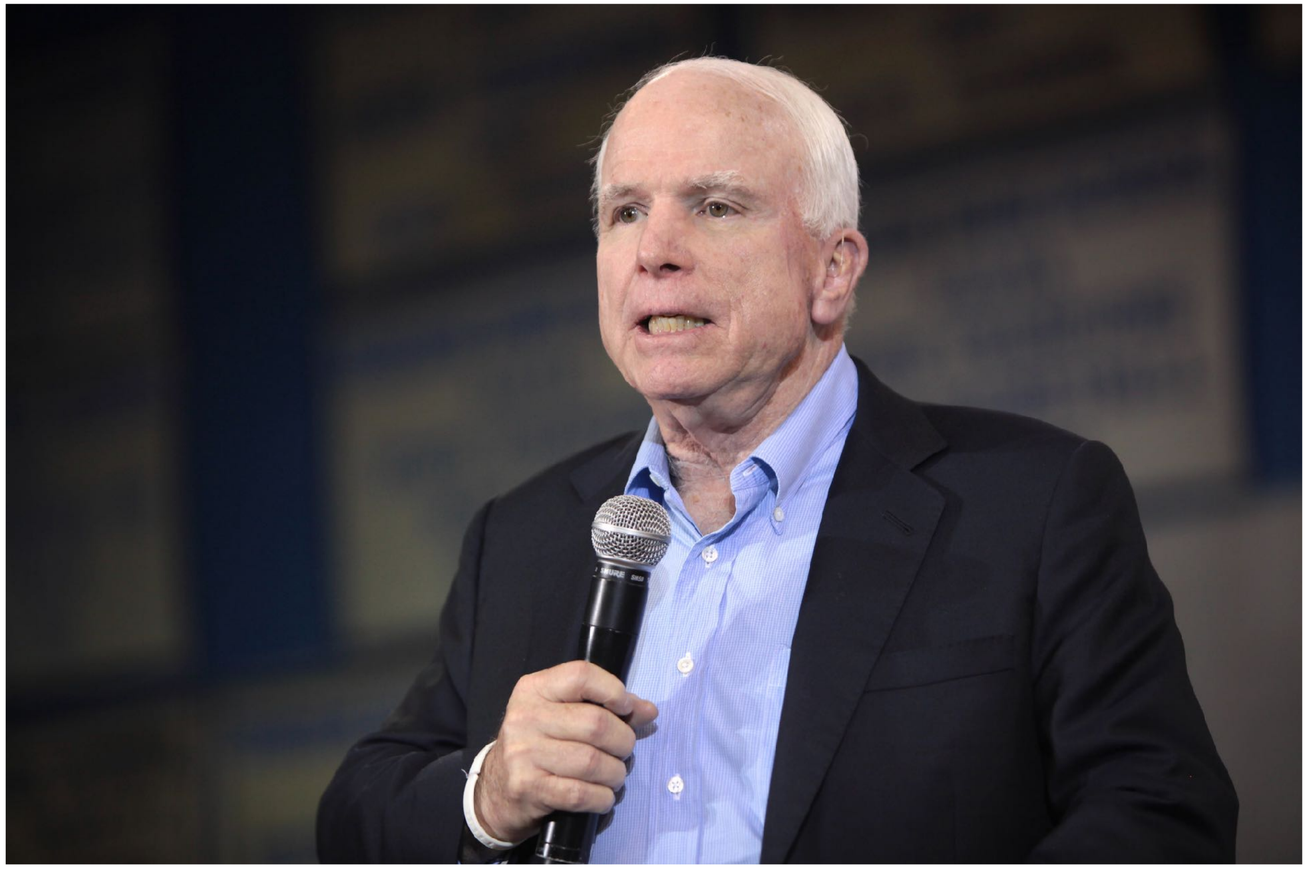
The View from Lynx

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*

Spaceship One *X-Prize winner, 2004*

Spaceship Two... *announced 2005*

Spaceship Two Design

Spaceport America *New Mexico, 2011*

Image courtesy of Virgin Galactic

Spaceport America *New Mexico, 2011*

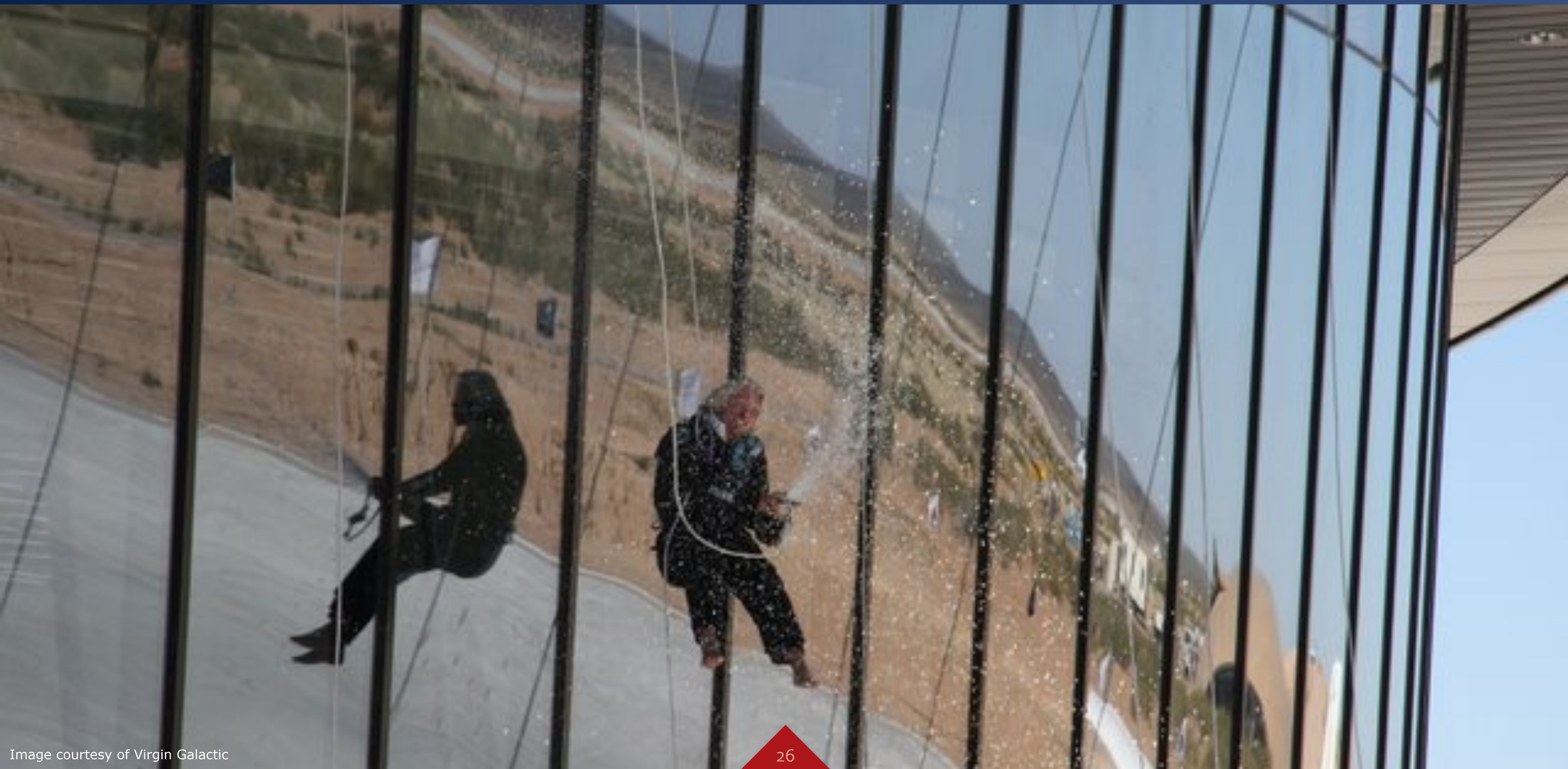


Image courtesy of Virgin Galactic

SpaceShip Two Drop Test *October 2010*

Image courtesy of Virgin Galactic

SpaceShip Two Powered Flight *April 2013*

Image courtesy of Virgin Galactic

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*

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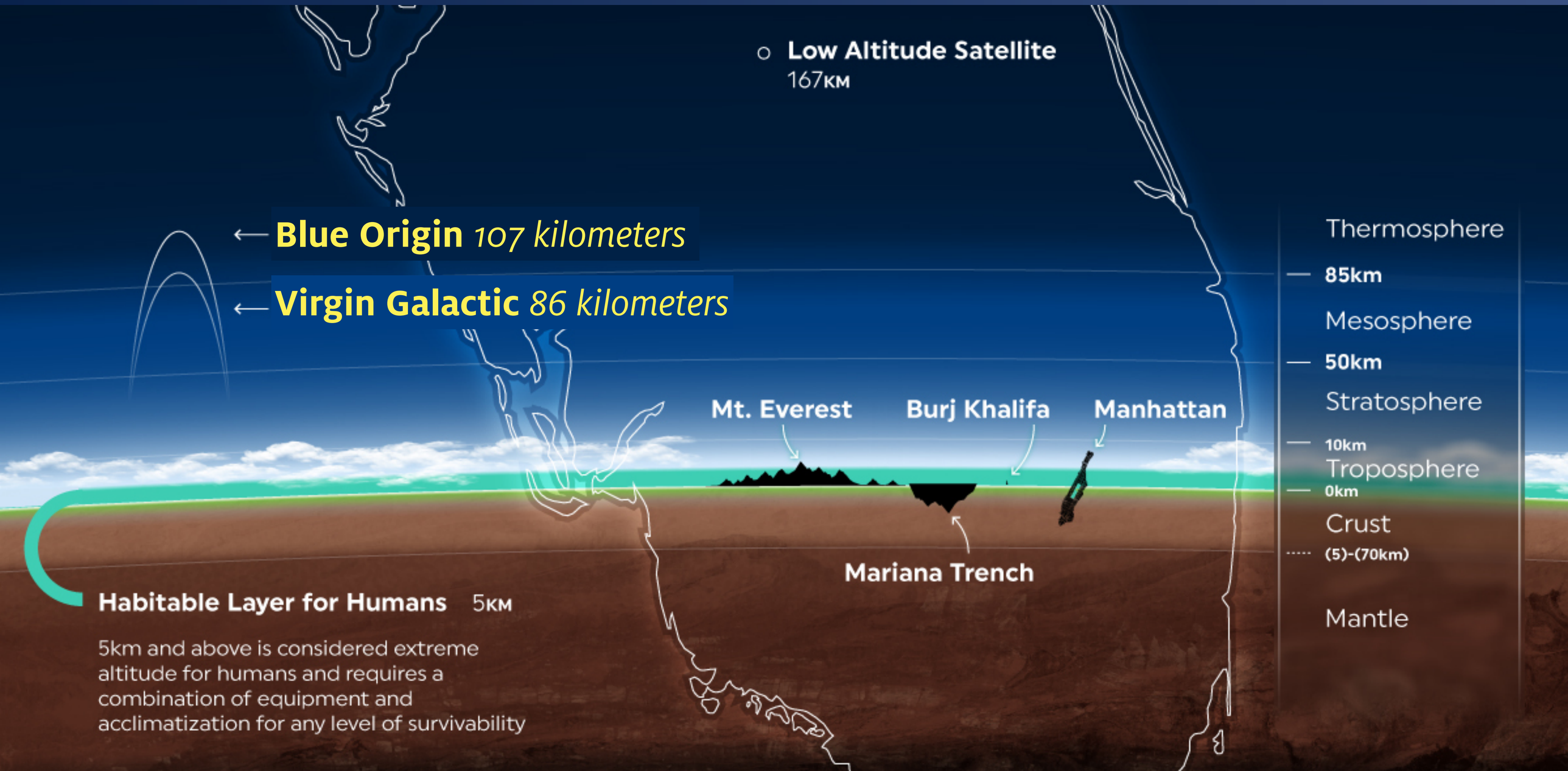
Blue Origin *20 July 2021*

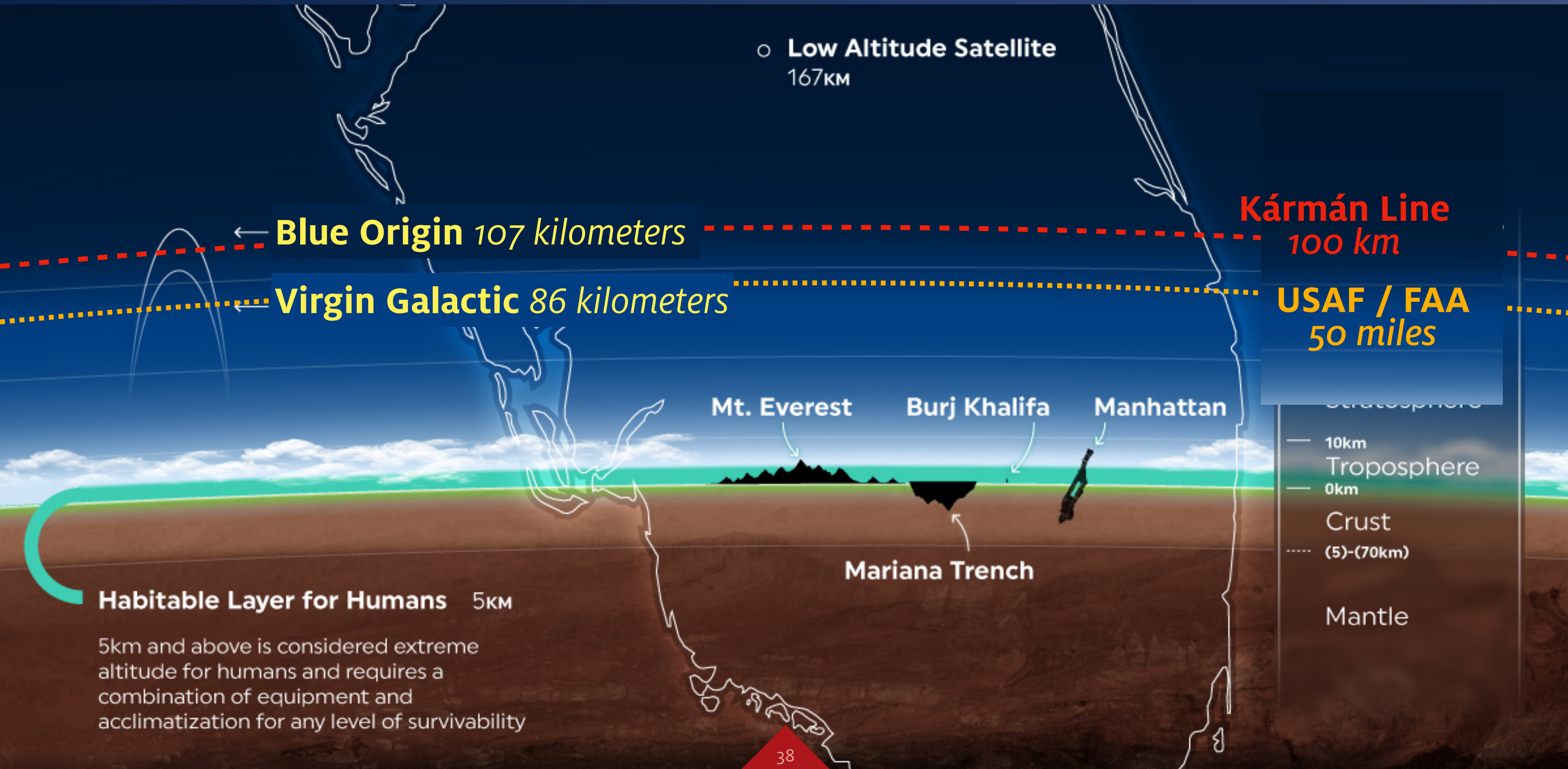
Blue Origin *20 July 2021*

After 17 Years, a Dead Heat!

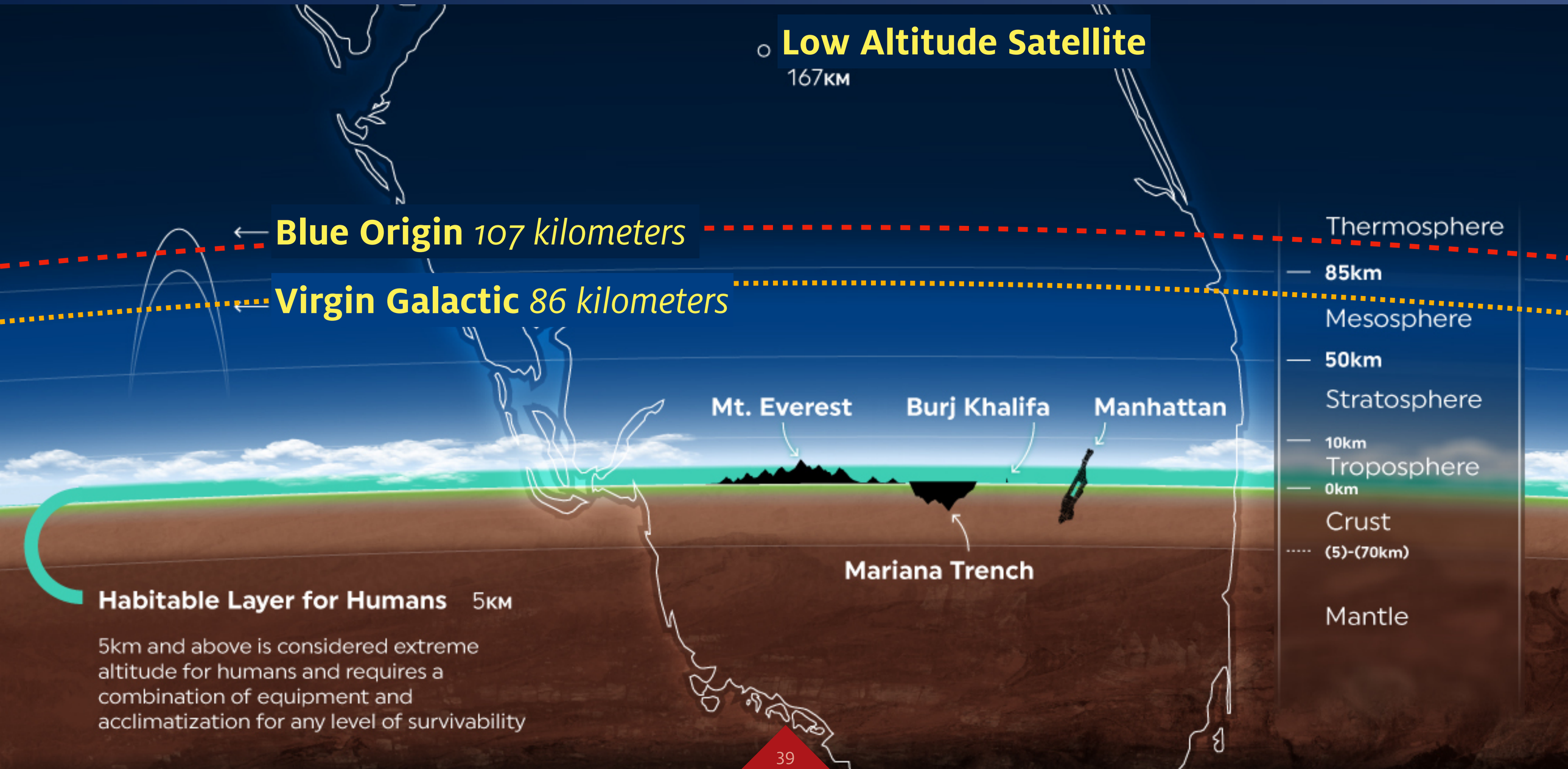
Did They Go to Space? *Or to Space* ?*



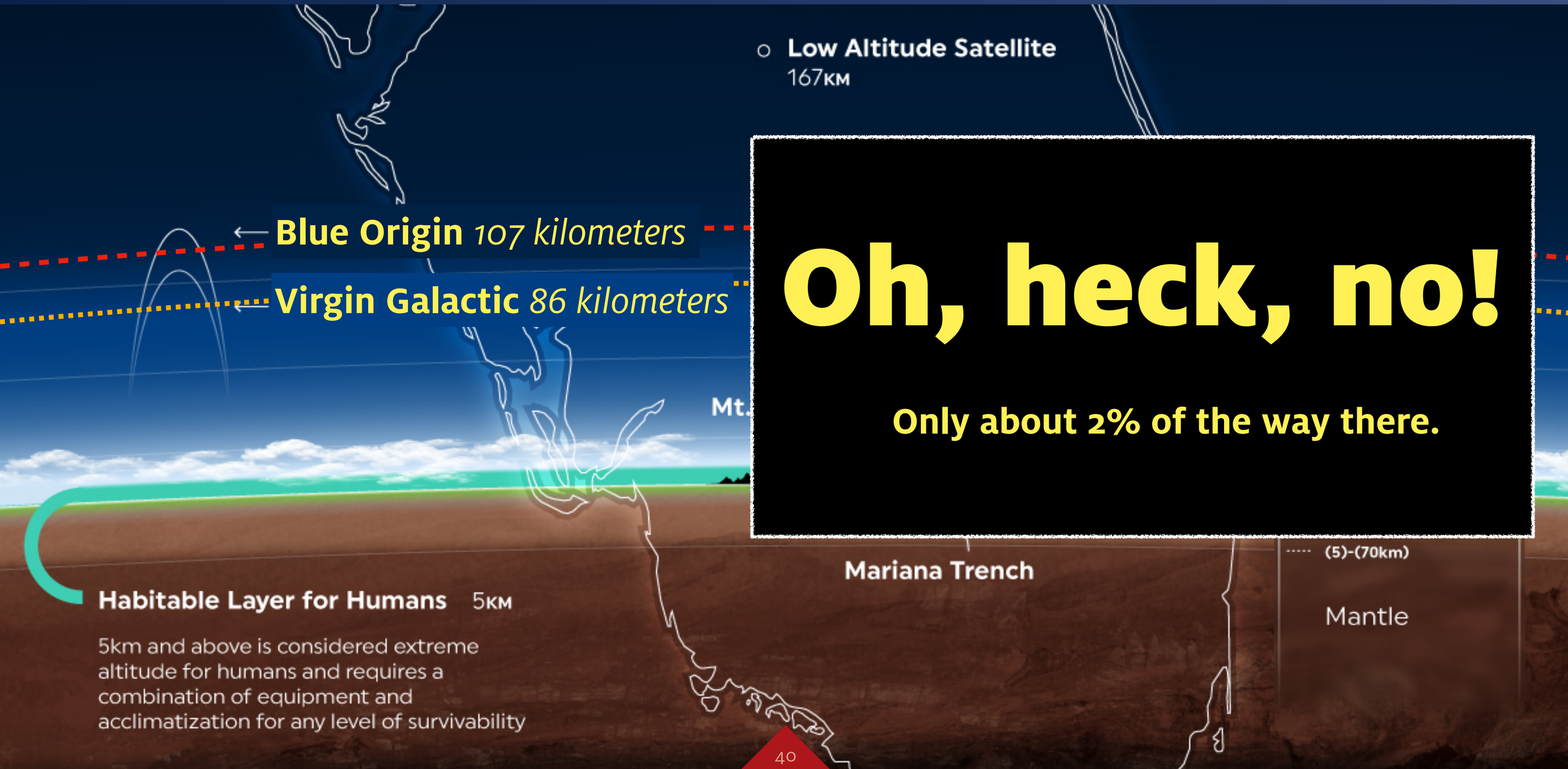
Did They Go to Space? *Or to Space* ?*

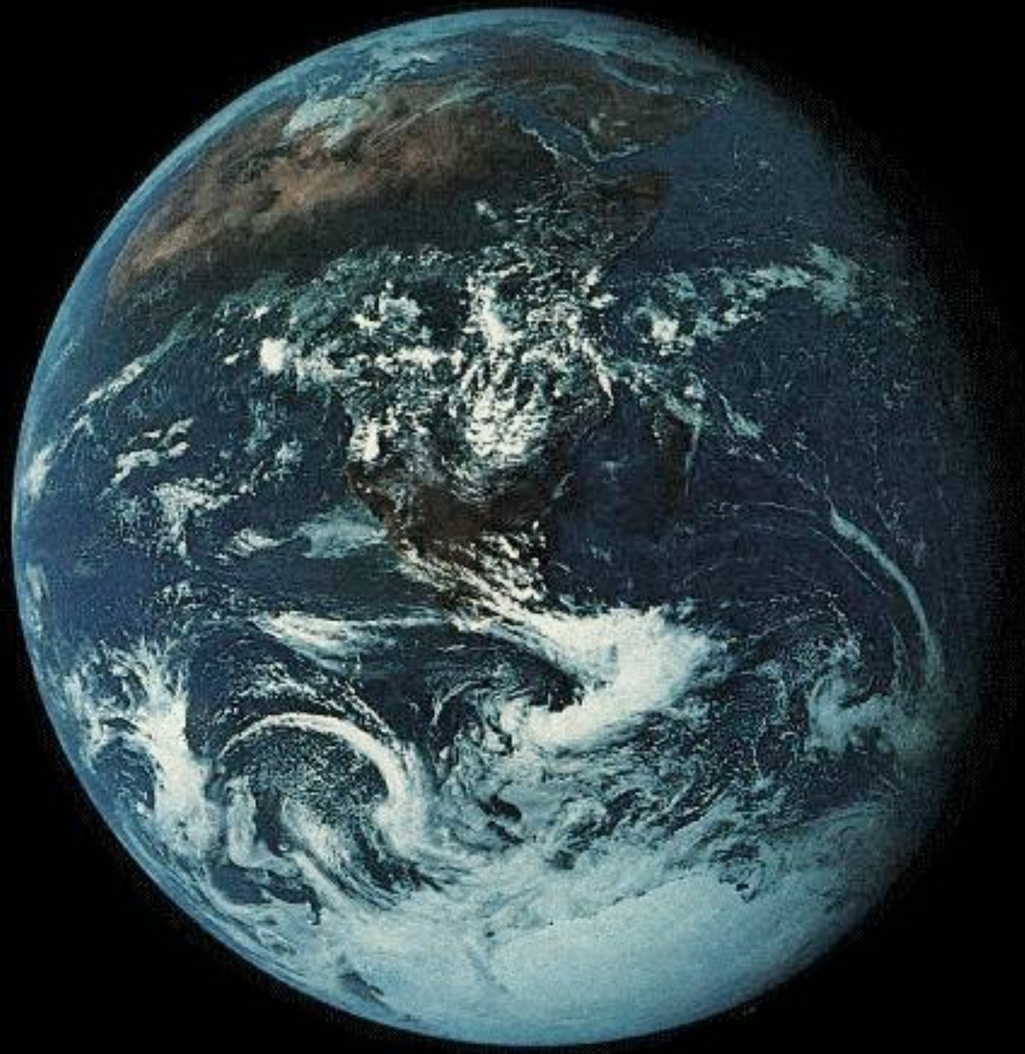


Did They Go to Orbit?

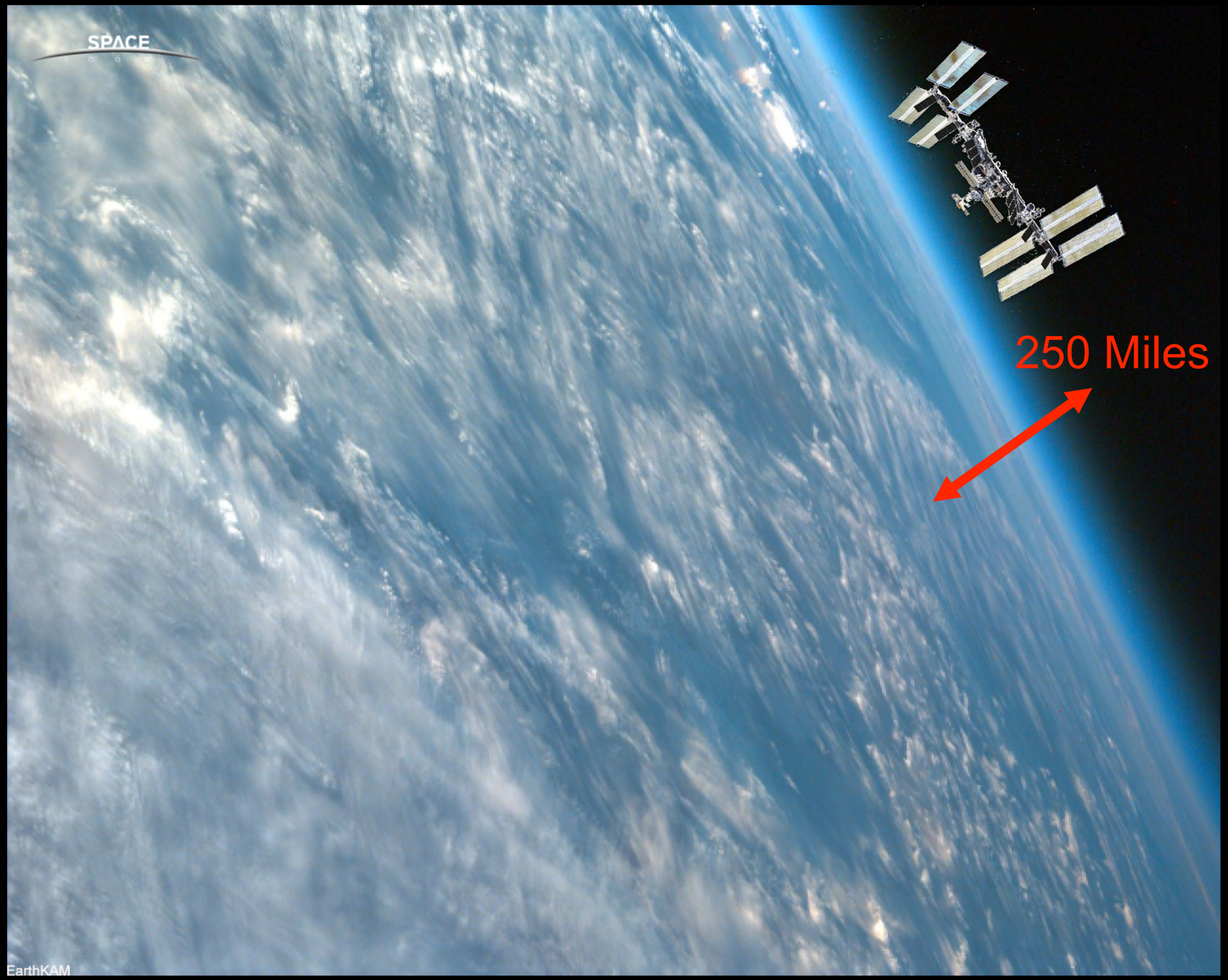


Did They Go to *Orbit*?



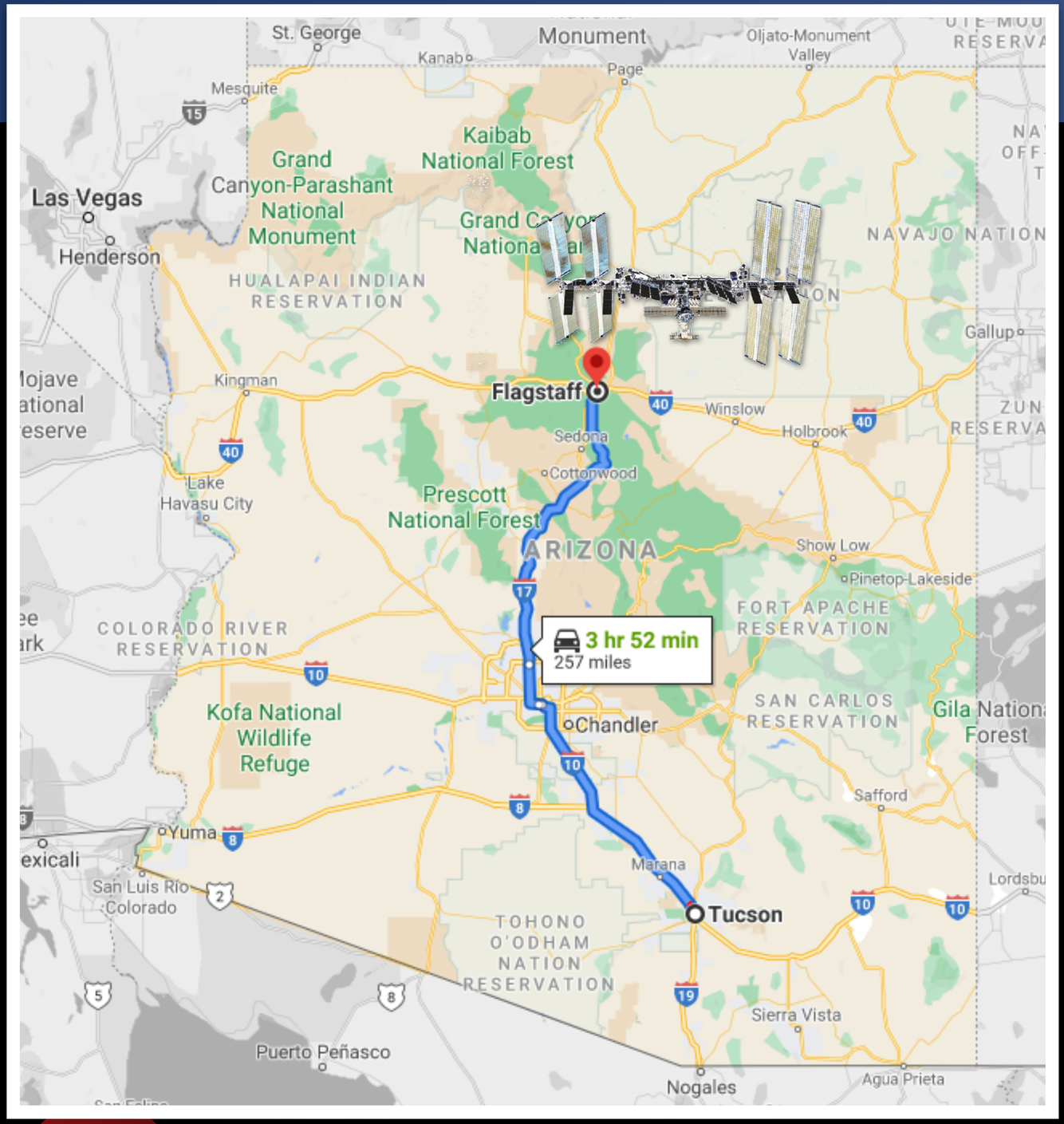


ISS Orbit *(to scale)*

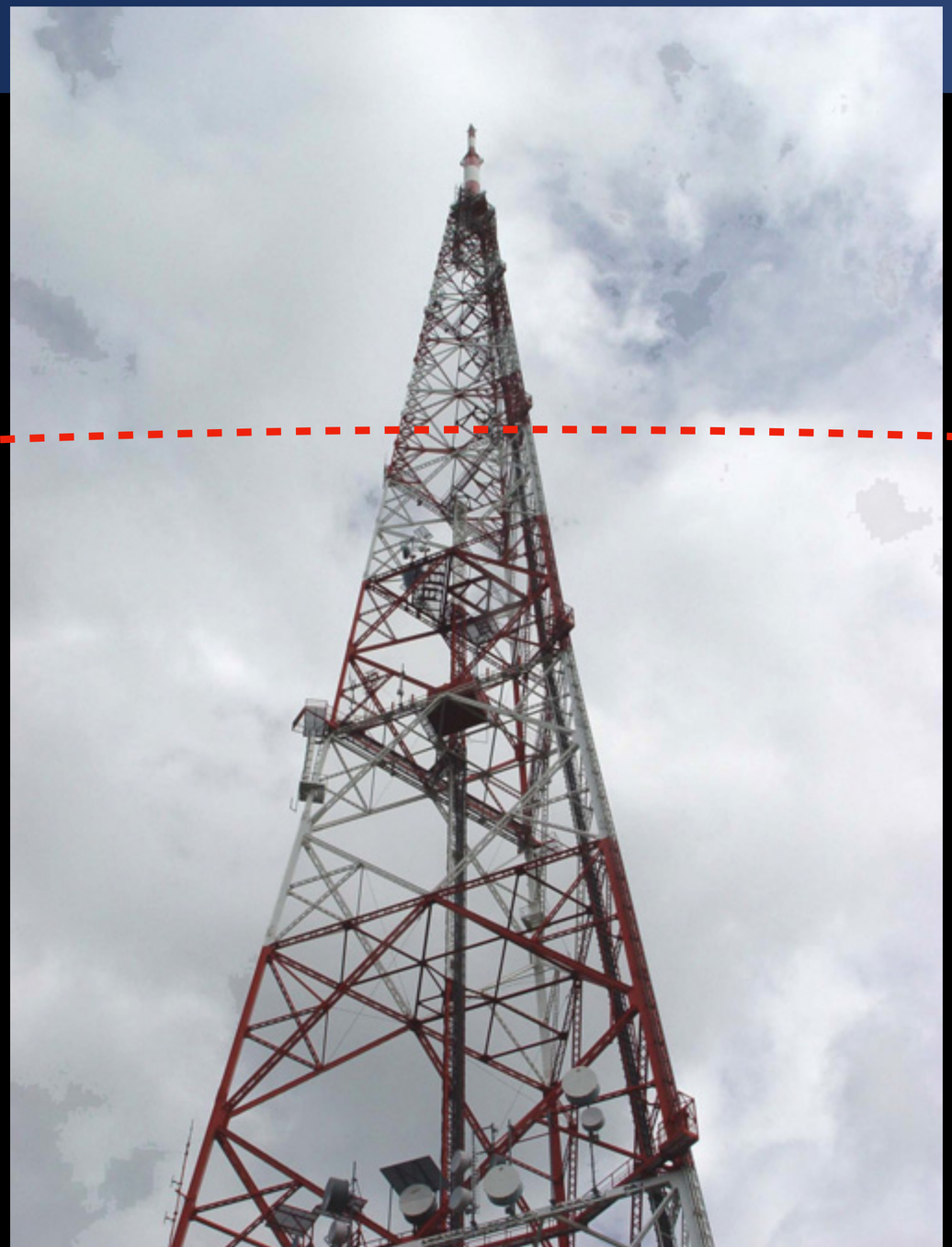

SPACE
250 Miles
EarthKAM

250 Miles

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



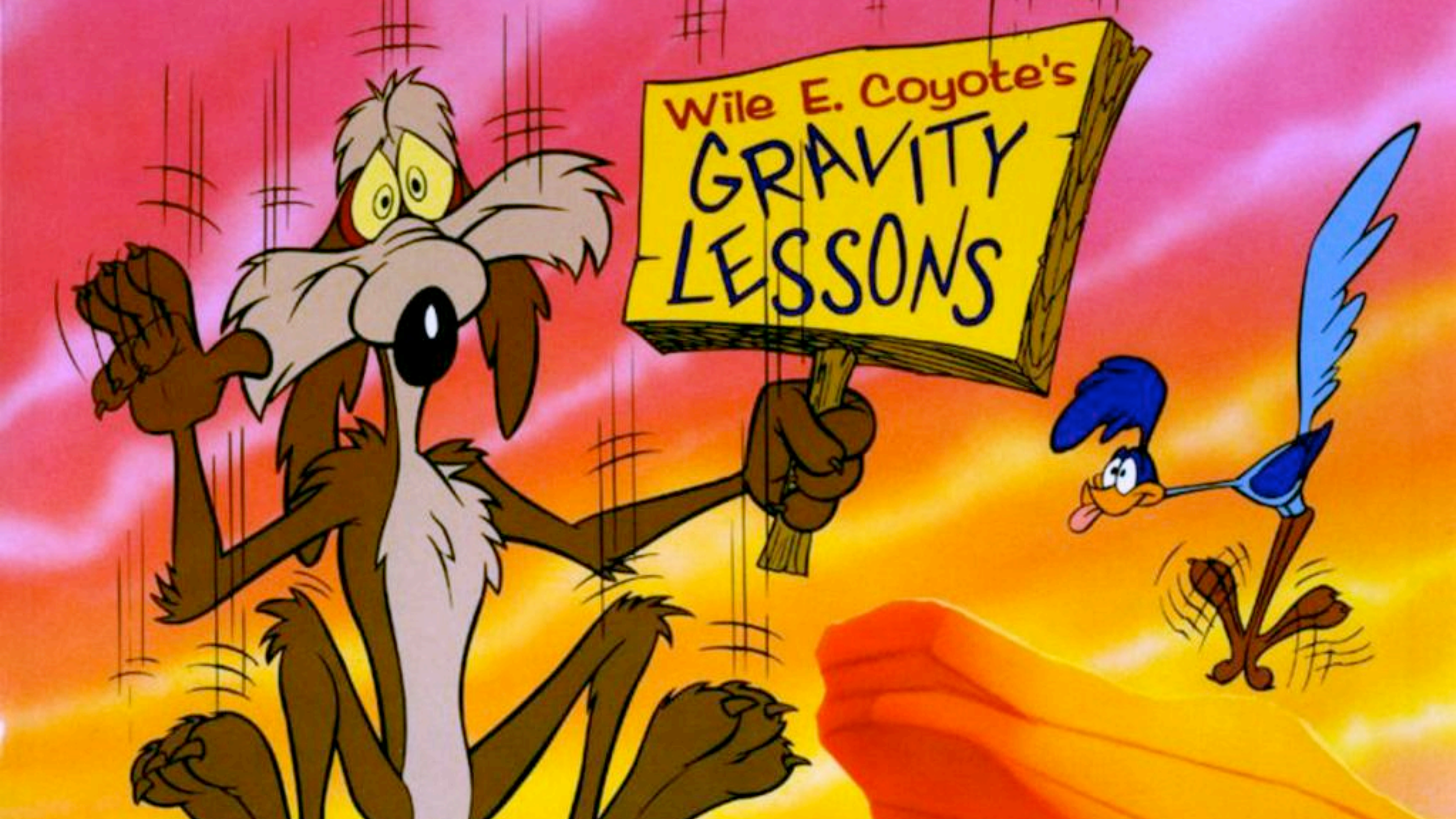
Altitude

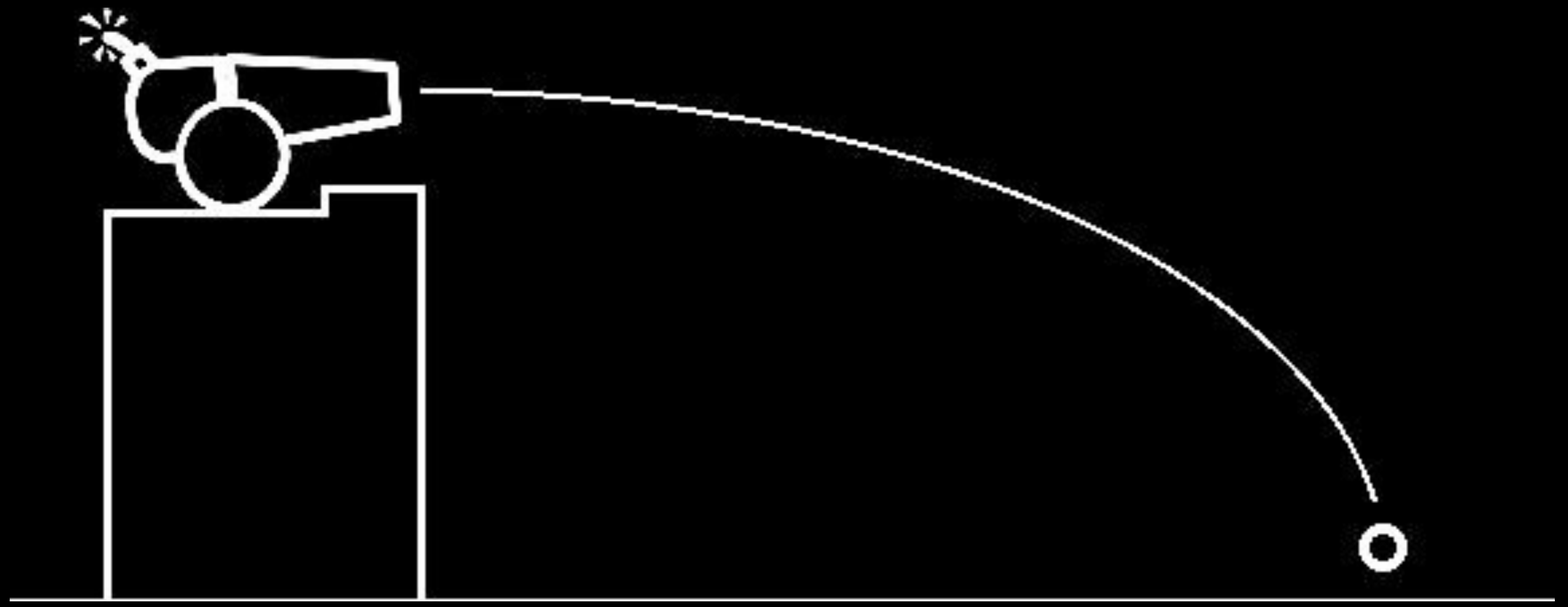


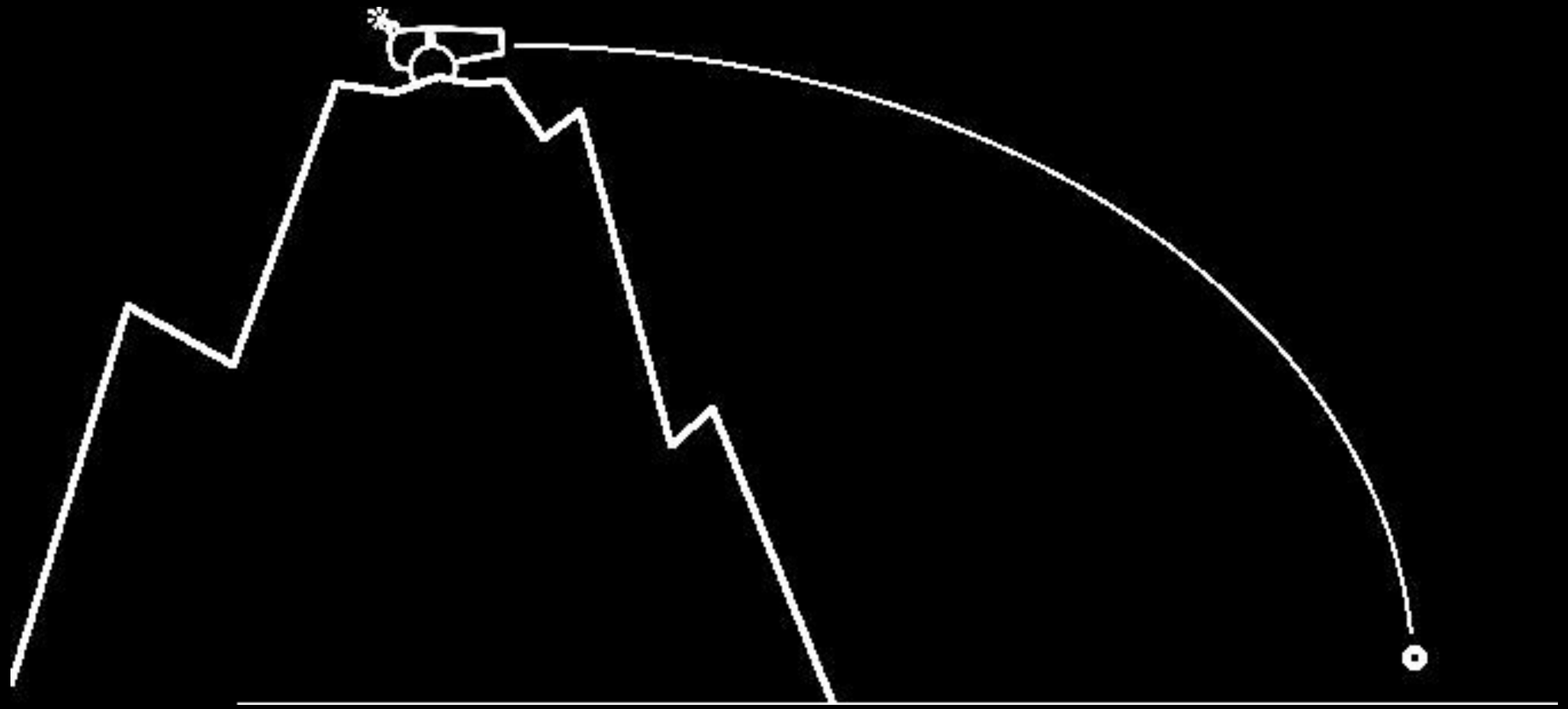
Kármán Line

100 km

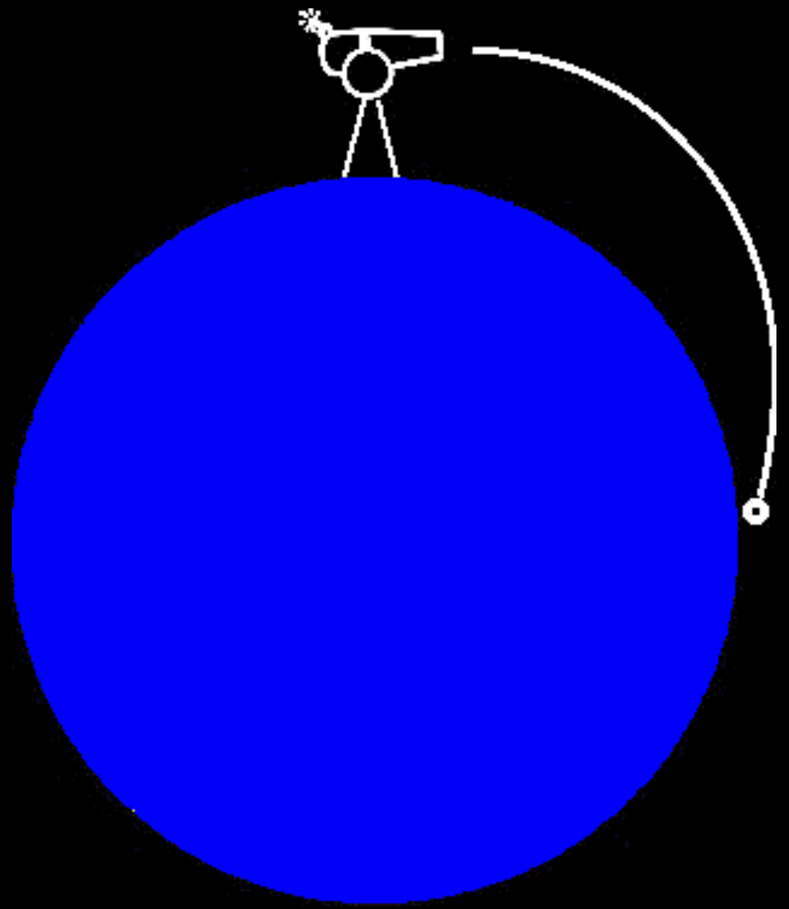
Orbital Altitude

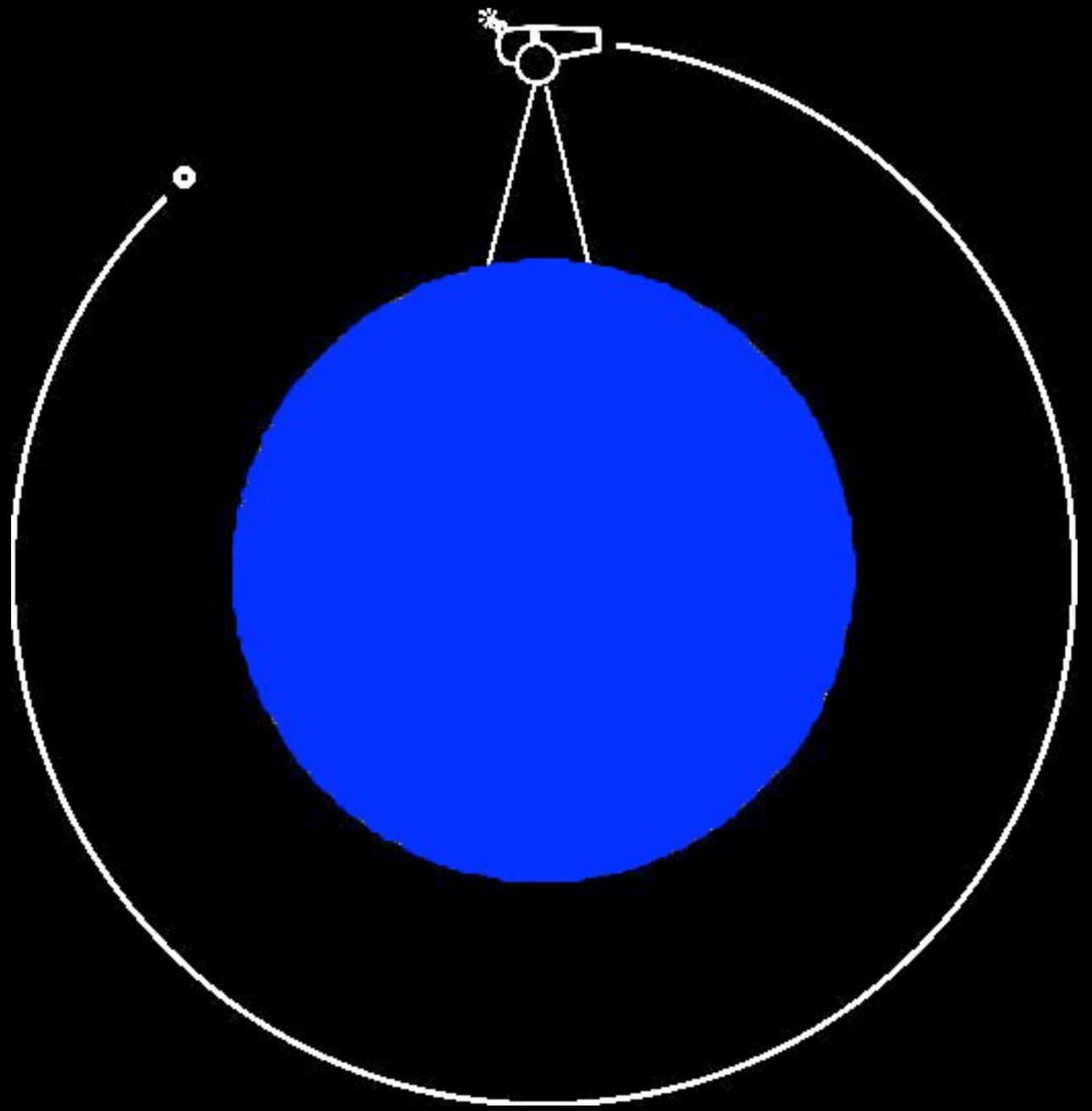

Wile E. Coyote's
GRAVITY
LESSONS

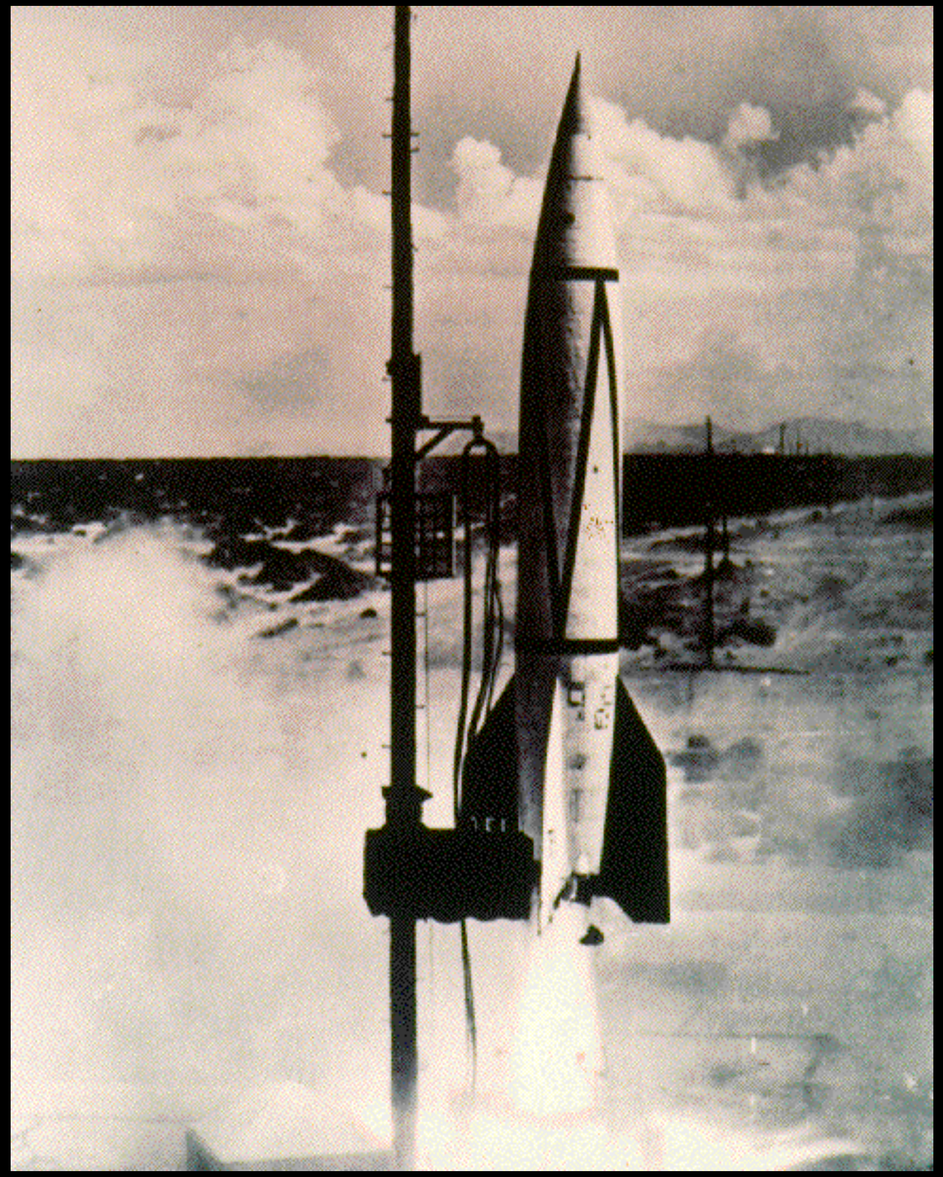




The World is not Flat!








USA

Rockets go Sideways

$v = \frac{dx}{dt}$ (trick)

$$m v \frac{dv}{dt} = -\frac{GMm}{x^2}\frac{dx}{dt}$$

integrate, but stop at 1 AU - comet doesn't crash.

final speed → v_f, initial speed → 0

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

x_f ← final location → don't use $x_f = 0$ (why?)

x_0 ← initial location, $x_0 = 50\,000$ AU

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

The choice of x_f is arbitrary!

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

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

$M \simeq 2 \times 10^{30}$ kg

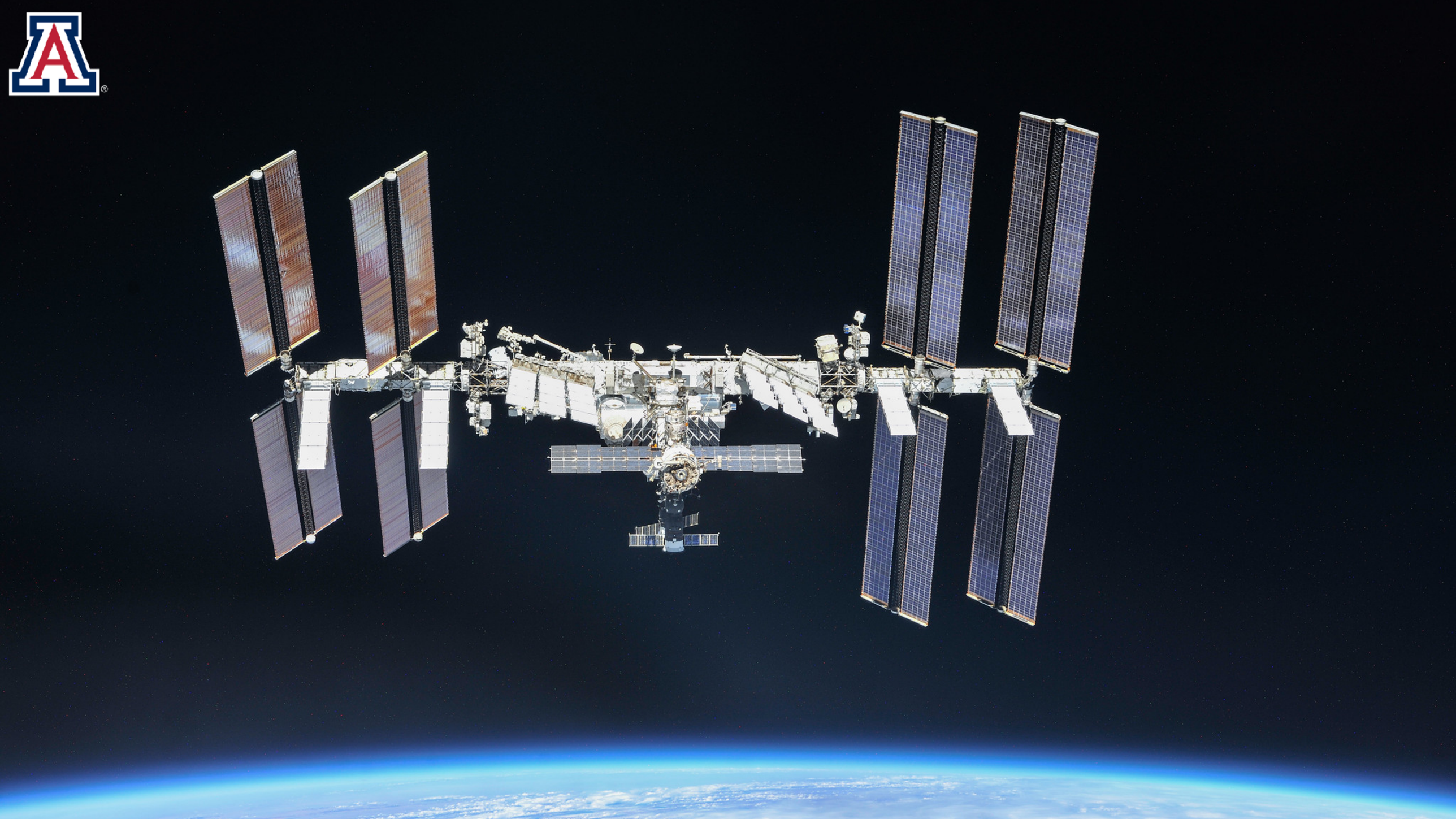
$v_f \simeq 42$ km/s

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

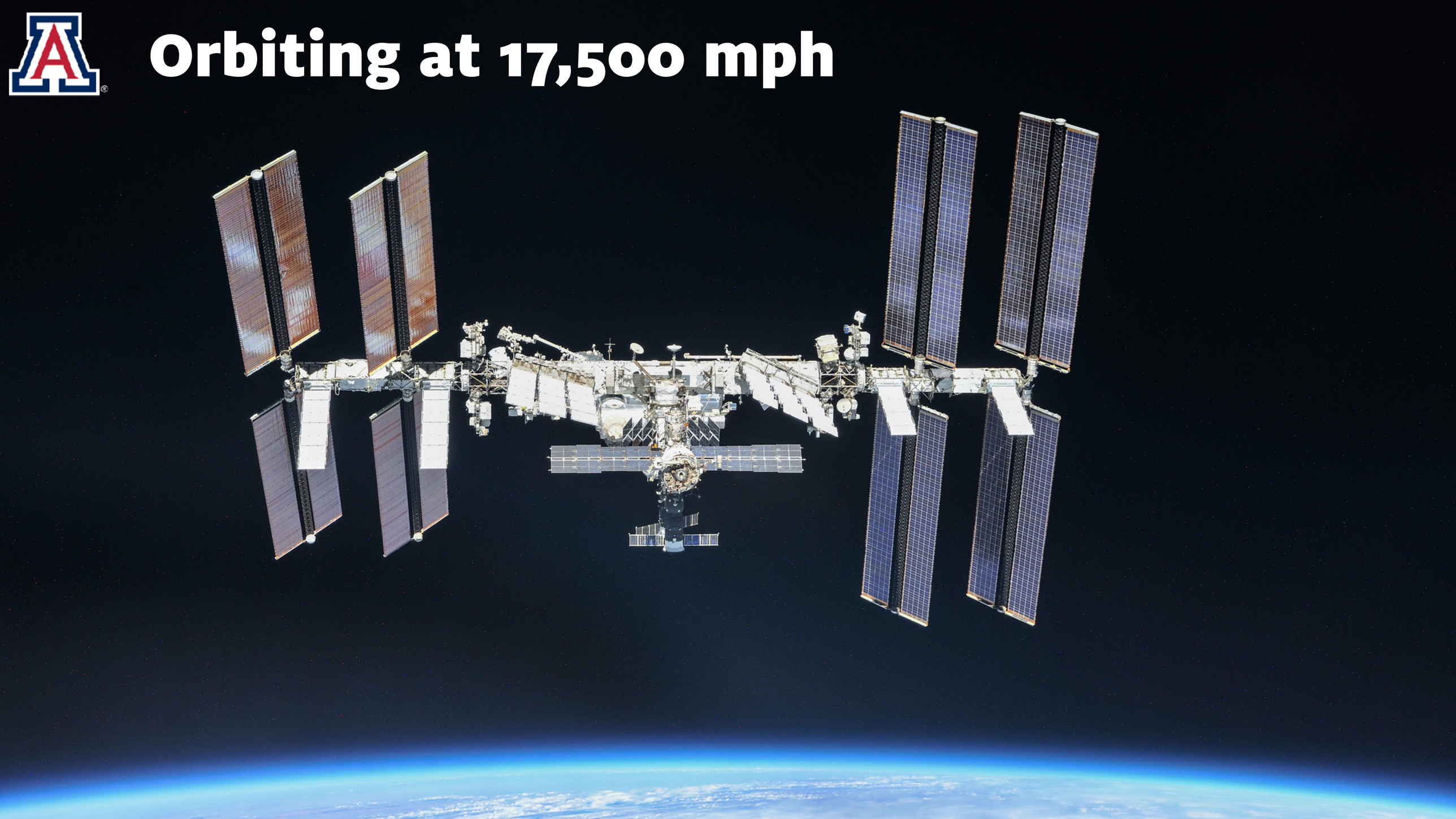
$$t_f = \int_0^{t_f} dt = -\int_{x_0}^{x_f} \frac{dx}{\sqrt{2GM\left(\frac{1}{x} - \frac{1}{x_0}\right)}} = \frac{2}{3}\frac{1}{\sqrt{2GM}}\left(x_0^{3/2} - x_f^{3/2}\right)$$

← negligible? No, choose $U(x_0) = 0$

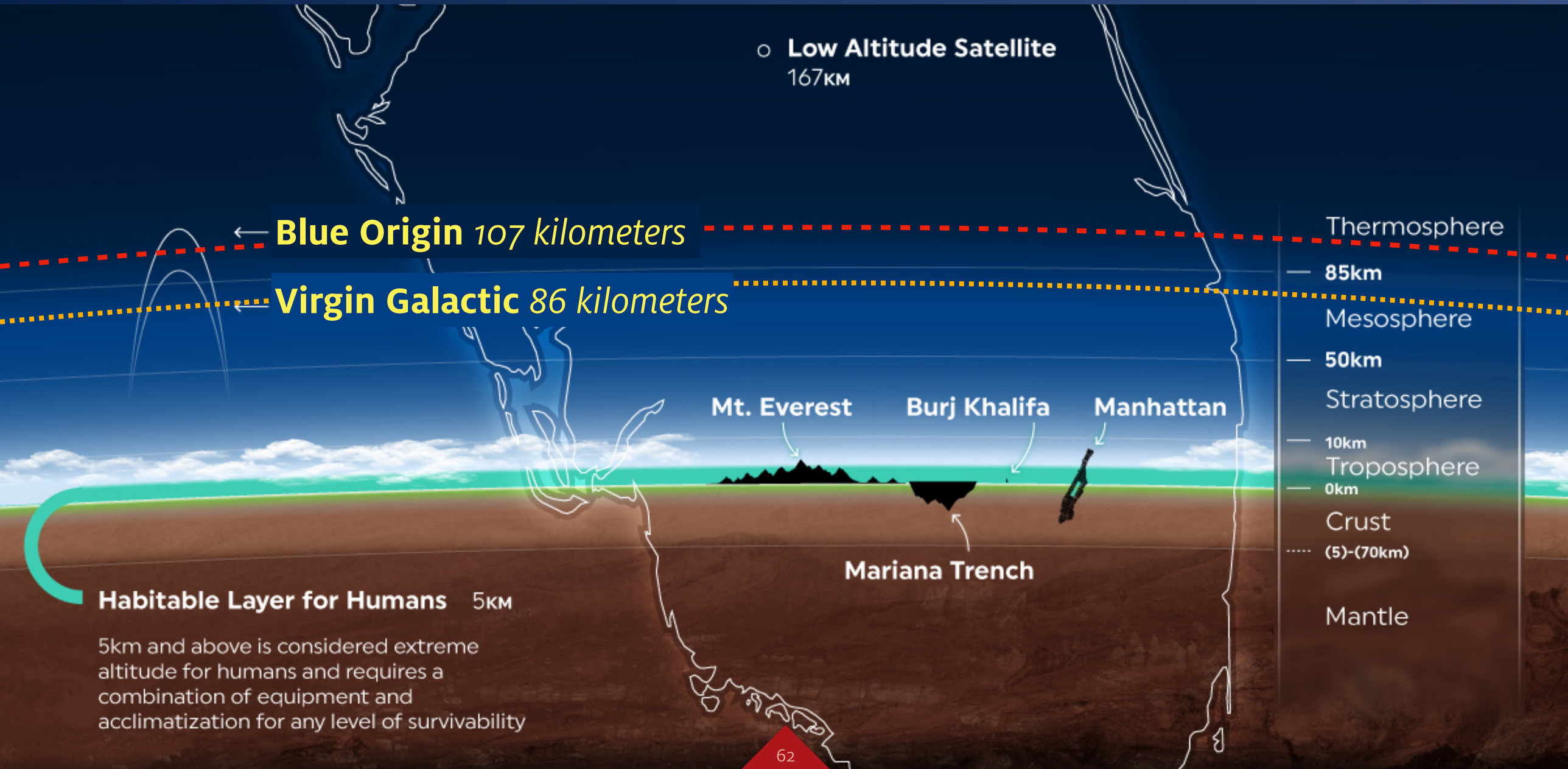
$$t_f \approx \frac{2}{3}\frac{1}{\sqrt{2GM}} x_0^{3/2} \simeq 4 \times 10^{13}\ \text{s} \simeq 1.3 \times 10^6\ \text{years}$$



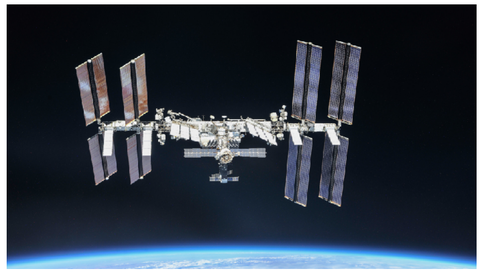
Orbiting at 17,500 mph



Did They Go to Orbit?



Comparison of Velocities



International Space Station

Alan Shepard,
suborbital flight, 1961

Spaceship Two

Only ~14% of orbital velocity

Blue Origin “New Shepard”

Orbital Velocity: 17,500 mph

Suborbital max velocity
5,134 mph

Suborbital max velocity:
2,485 mph

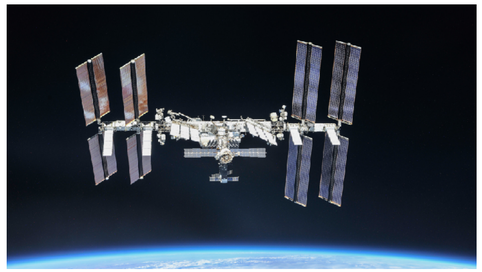
Suborbital max velocity:
2,217 mph

But… what about Kinetic Energy?

$$KE = \frac{1}{2} mv^2$$

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

Comparison of Kinetic Energies



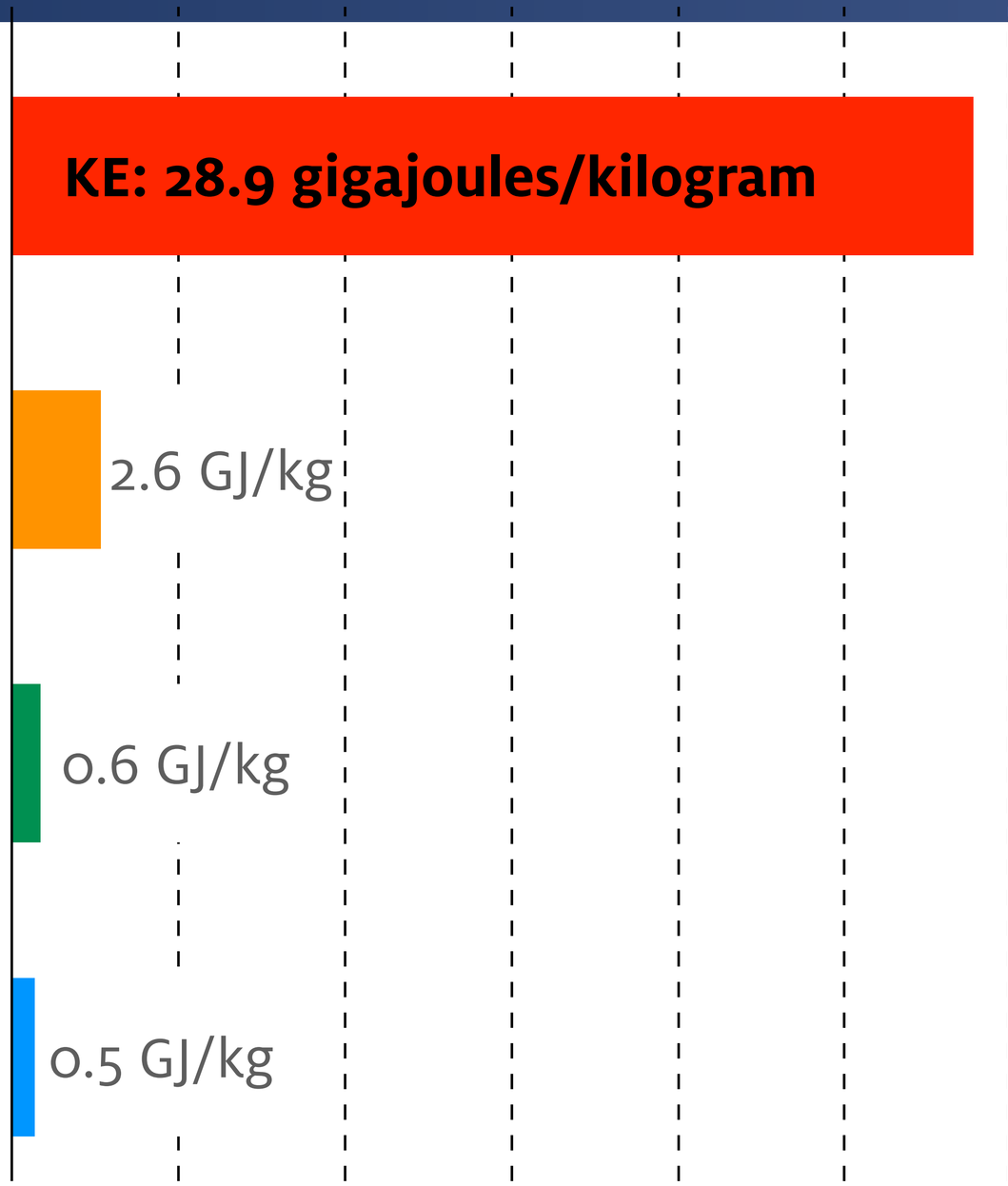
International Space Station

Alan Shepard,
suborbital flight, 1961

Spaceship Two

Only ~2% of orbital ***energy***

Blue Origin “New Shepard”

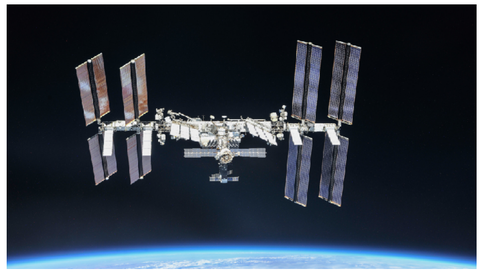


Imagine Converting Ice to Steam…

6.8 megajoules per kilogram

Now Imagine Tank Cars Full of Ice…

KE = How Much Ice to Steam?



International Space Station

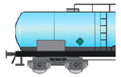
Alan Shepard,
suborbital flight, 1961

102,000 gallons

Spaceship Two

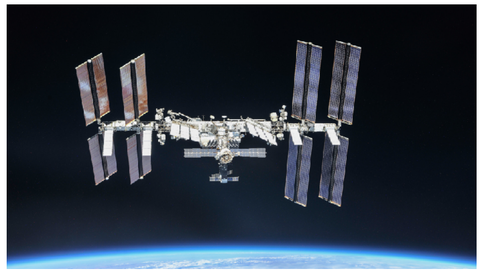
Equivalent of converting
24,000 gallons of ice to steam

Blue Origin “New Shepard”

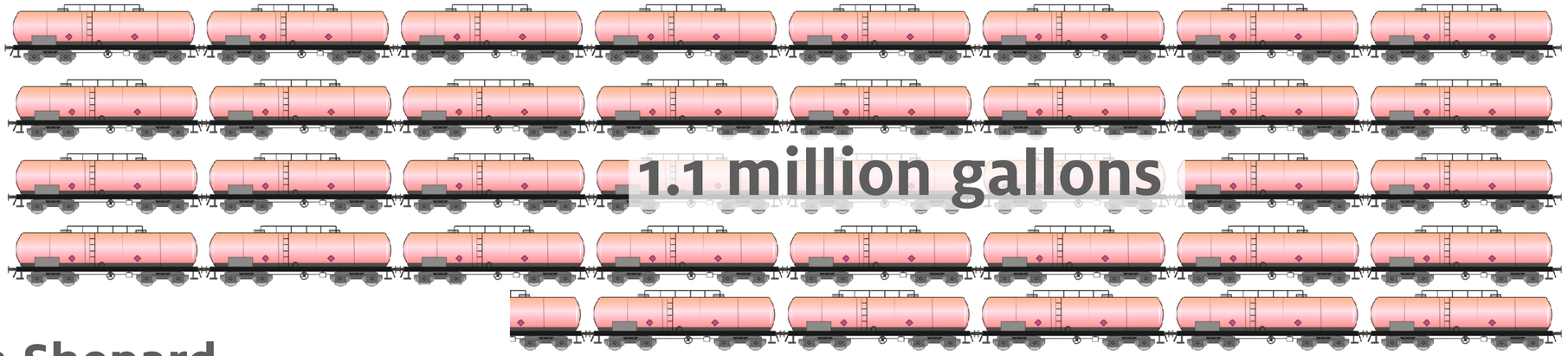


19,000 gallons

KE = How Much Ice to Steam?



ISS



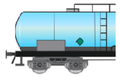
Alan Shepard, suborbital flight, 1961

102,000 gallons

Spaceship Two

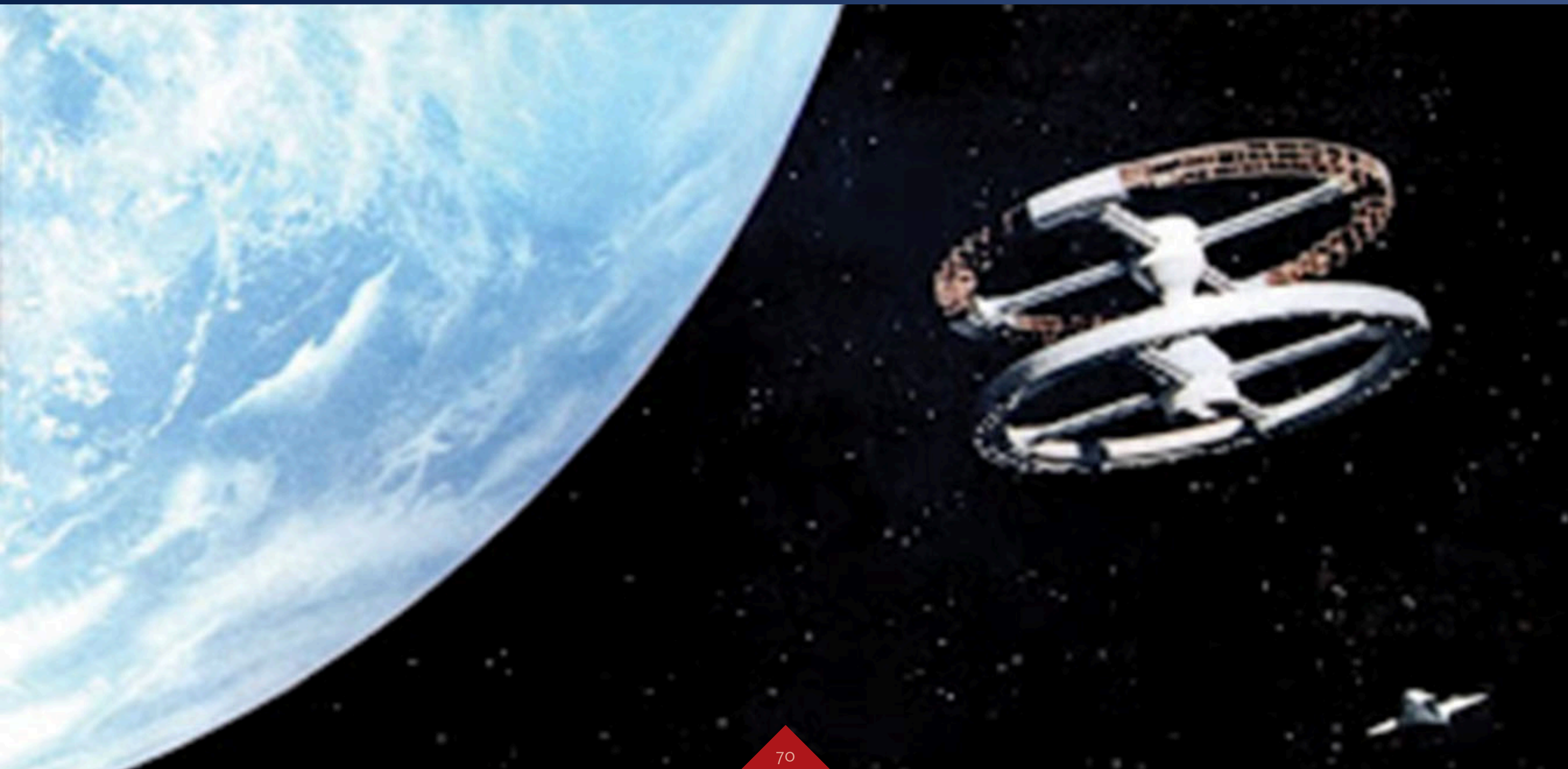
Equivalent of converting 24,000 gallons of ice to steam

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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