Near Term Space Settlement: Risk Reduction Missions

Kent Nebergall
Macroinvent.com

Mars Society Conference, 2017

The Grand Challenges of Space Settlement (2014)

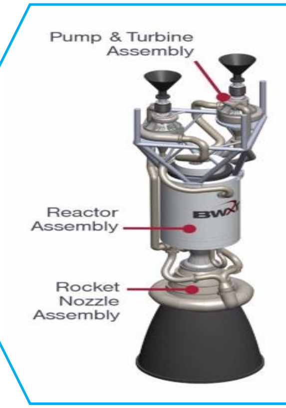
Launch/LEO	Deep Space	Moon/Mars	Settlement
Affordable Launch	Solar Flares	Moon Landing	Air/Water
Large Vehicle Launch	GCR: Cell Damage	Mars EDL	Fuel
Mass Fraction beyond Earth Orbit (Refueling)	Medication/ Food Expiration	Spacesuit Lifespan	Power
Space Junk	Life Support Closed Loop	Reliable Ascent Vehicle	Food
Microgravity (health issues)	Medical Entropy	Reliable Return Vehicle in Orbit	Assembly
	Psychology	Flight to Earth	Mining
	Mechanical Entropy	Earth Reentry	Manufacture
Funded Projects	NASA Focus	Commercial Focus	Gaps

Preparing for the NewSpace Revolution

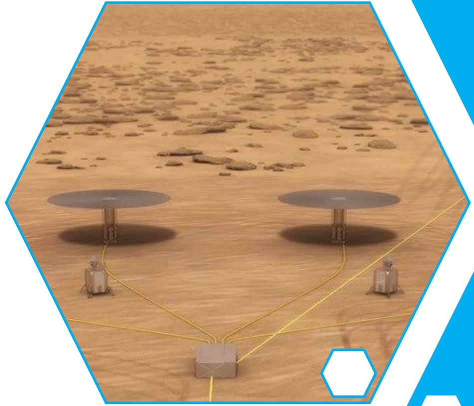
<table>
<tr><th>Year</th><th>Energy</th><th>Information</th><th>Invention</th><th>Affordability</th></tr>
<tr><td>2017</td><td rowspan="3">Falcon Heavy</td><td></td><td></td><td rowspan="3">Falcon 9 Block 5
Crewed Dragon
Crewed Starliner</td></tr>
<tr><td>2018</td><td></td><td rowspan="2">Blockchain Matures</td></tr>
<tr><td>2019</td><td rowspan="4">Low Latency Global Internet Satellites

AI Capabilities</td></tr>
<tr><td>2020</td><td rowspan="2">New Glenn</td><td>LEO Internet
Bigelow BA330</td><td rowspan="3">50 MT satellites have two launch platforms, both cheap and rapid turnaround</td></tr>
<tr><td>2021</td><td>Quantum Computing?</td></tr>
<tr><td>2022</td><td>NASA Space Nuclear Power
Nuclear propulsion</td><td>ISS Replacement Groundwork</td></tr>
</table>

NASA Nuclear Projects



BWXT Nuclear Thermal Rocket



TDU

10-100 KW

KiloPower

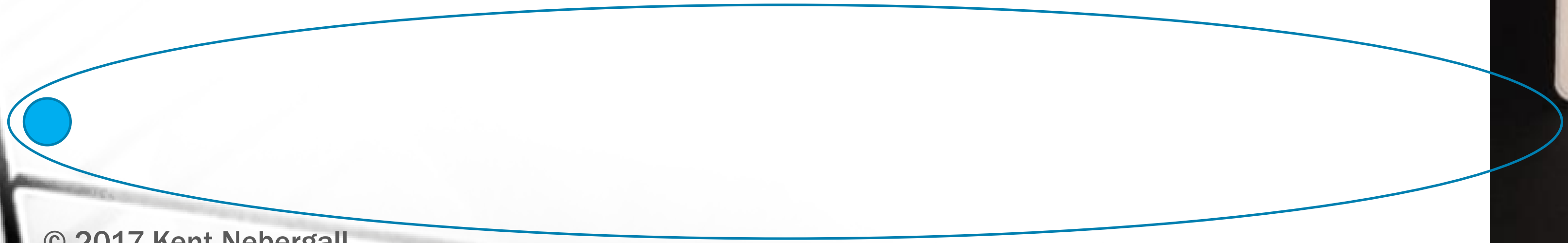
1-10 KW

Driving Critical Mass for the NewSpace Revolution

- Deep Space Risk Reduction Missions
- Organizing for Direct Solutions

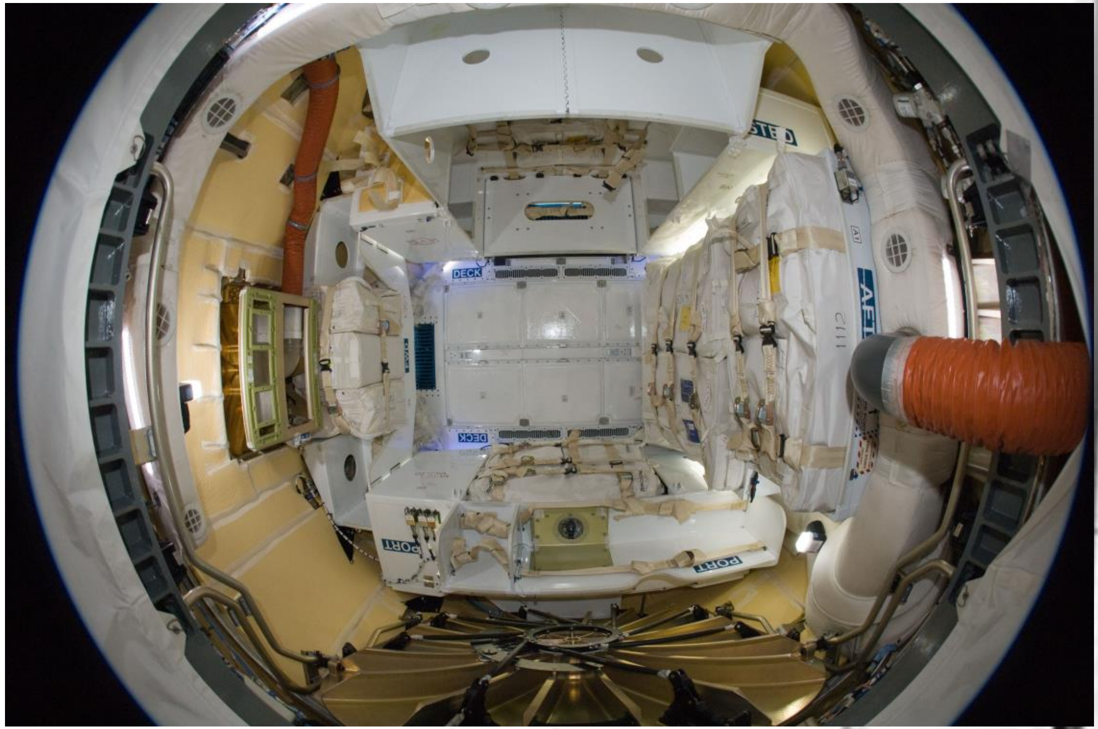
Deep Space DragonLab 1

- Exposure test items that are altered when exposed to deep space to test the risk
- Launch into high (lunar distance apogee) orbit to expose to unfiltered cosmic rays and solar flares
- After mission simulating full trip to/on/from Mars, return the cargo and examine results.
- Very small Delta-V needed to drop back into atmosphere from elliptical orbit.
- BONUS: Simulate Mars Return impact on heat shield



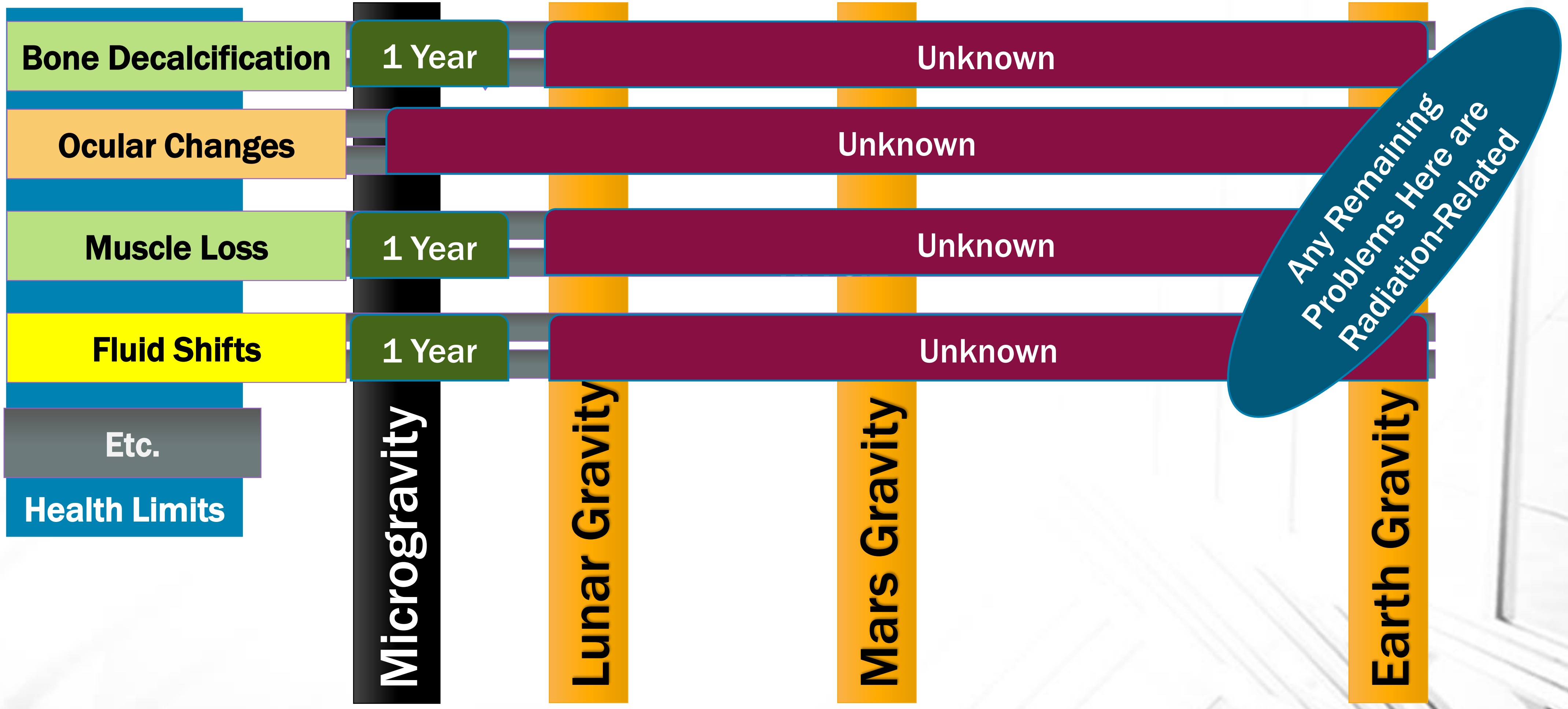
Lab Experiments

- Food with nutrients that degrade in radiation exposure, and full spectrum for use on mission
- Medication and vitamins known to loose efficacy, and those critical to mission
- Common pathogens that mutate harmfully in microgravity
- Seeds that would be grown for food on Mars
- Gut Bacteria and other microbiome life that may mutate or be impacted

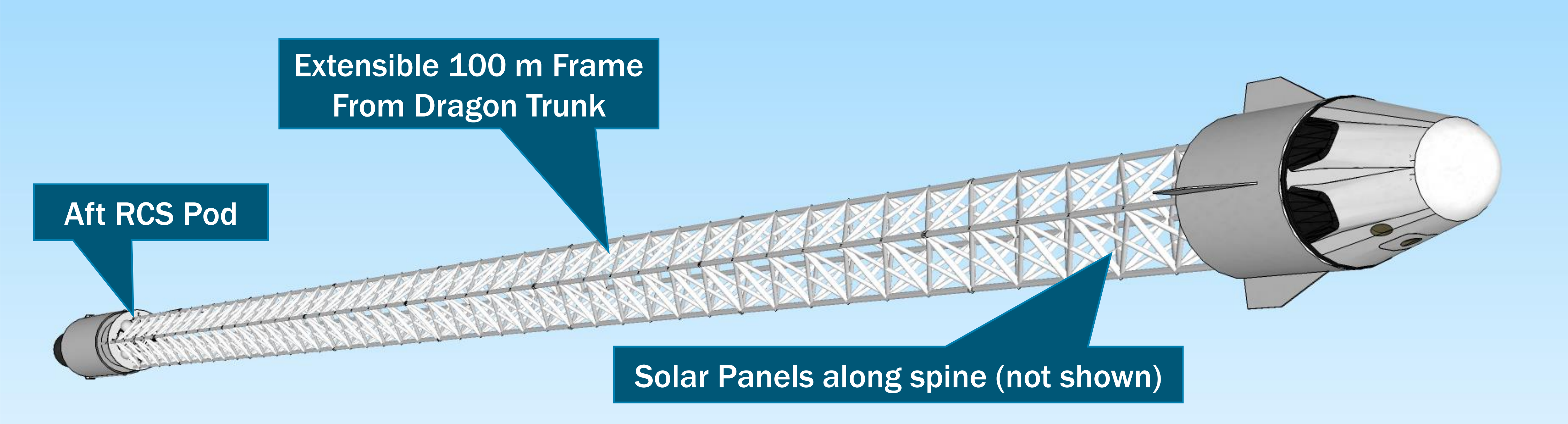


This Photo by Unknown Author is licensed under CC BY-SA

4 Bases: Full Spectrum Problem Characterization

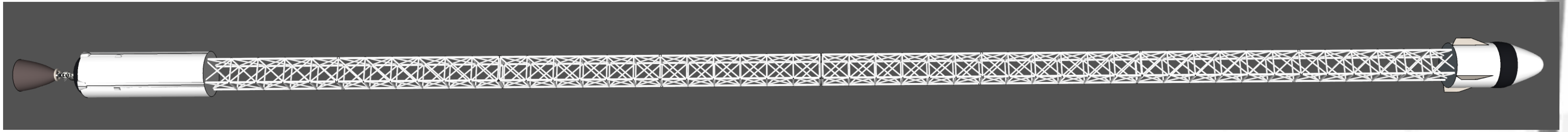


Deep Space DragonLab 2 (Spinning)



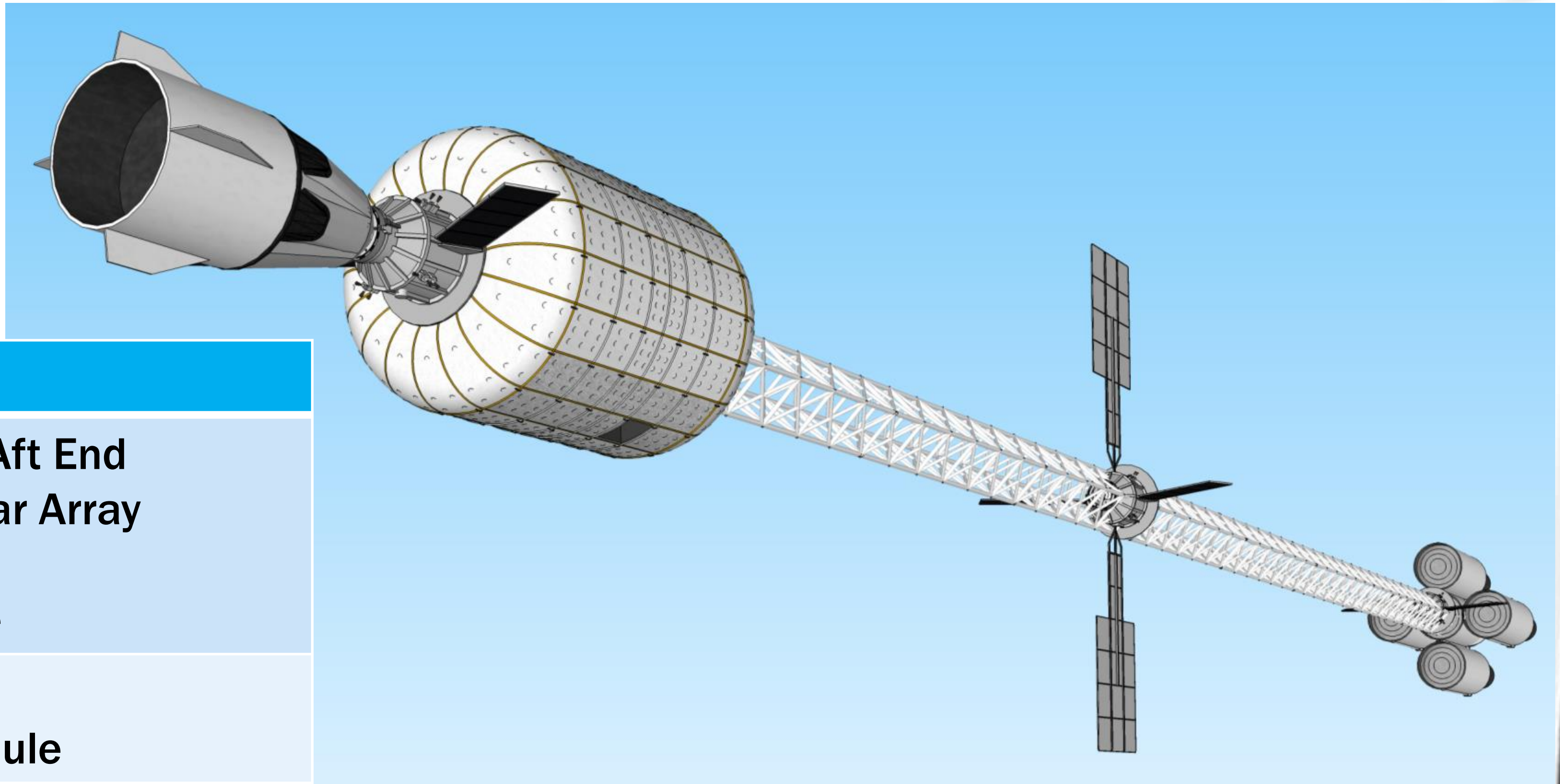
- Launch DragonLab and Second Stage into Same Orbit
- Made In Space Truss between the second stage and DragonLab to Spin (nominally 100 meters)
    - Corner cables for tension, truss for compression, with active stabilization by adjusting tension on cables.
- Include a Life Sciences Lab (multigenerational mouse-lab or equivalent)

Deep Space Spinning DragonLab 2 (“GameraLab”)



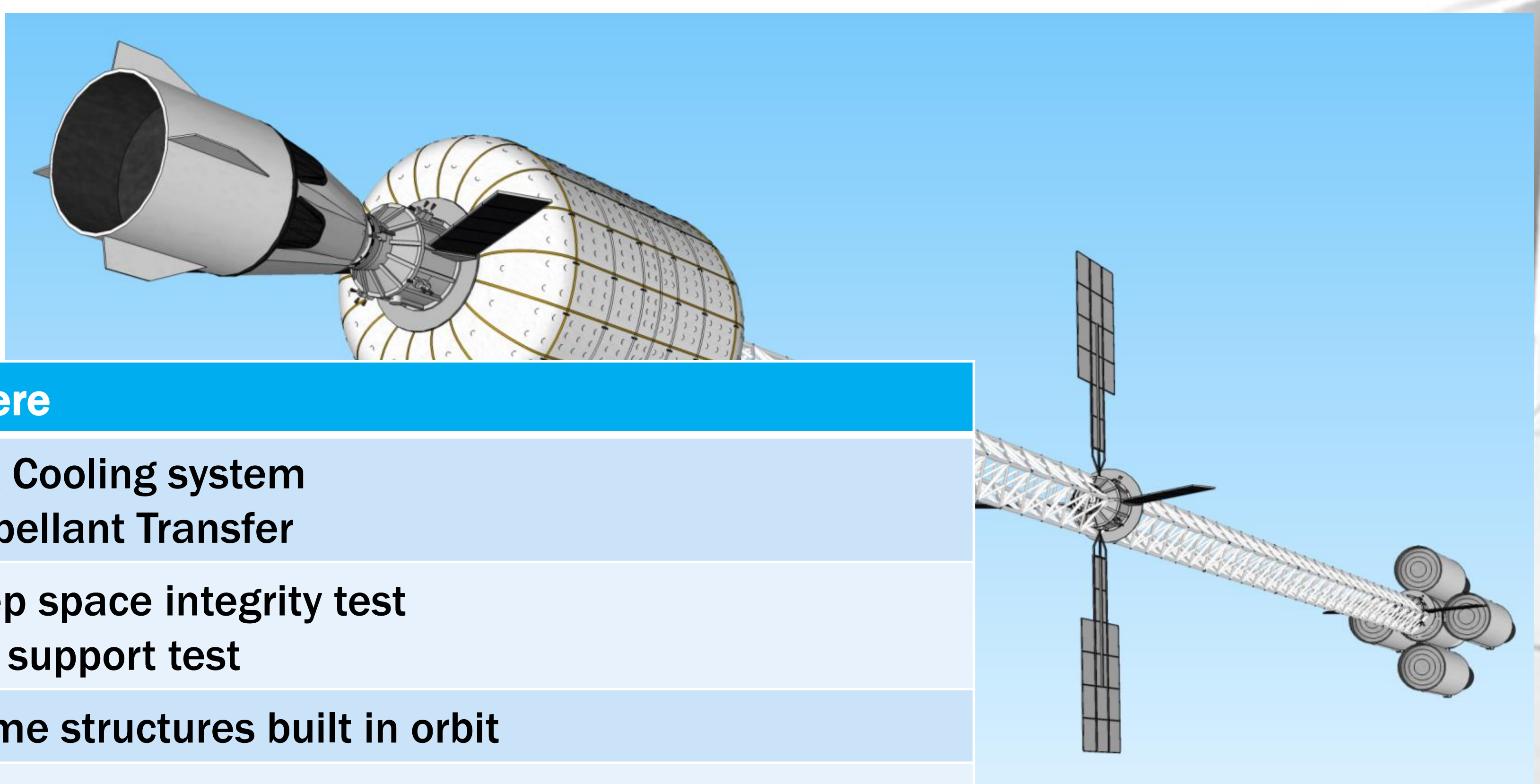
Variations	RPM	M/Sec	Purpose
Moon	1.8	8.34	• Simulate lunar occupation • Fast sample return (hours, not 3 days) from conditions to earth lab.
Mars	2.83	13.19	• Mars travel and settlement simulation • If able to handle conditions, may reduce the stress/need for fast/long tethers on crewed missions
Earth	4.5	20.85	• Control for conditions that are impacted by both radiation and reduced gravity • Fourth data point in the series to show trend lines

GameraLab Crewed



Launch	Payload
FH-1	• Propellant Dock at Aft End • Framework and Solar Array • RCS (Aft) • First Stage2 Module
FH-2	• BA-330 • Second Stage2 Module
F9-D	• Crew for Outfitting Lab • Third Stage 2 Module
FH-x	• Propellant Load/Add Stage2's
F9-D	• Crew for departure/Spin-up

Engineering Testbed

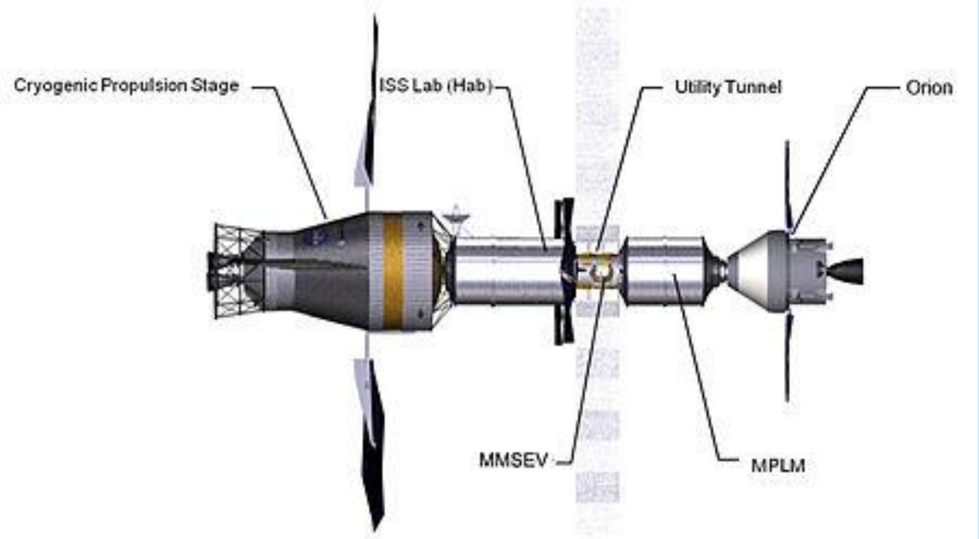


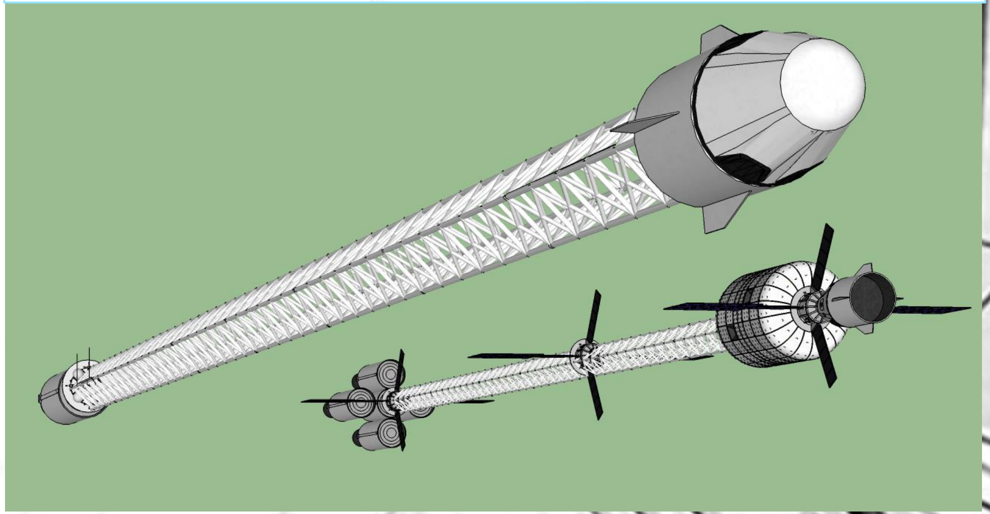
Needed for	Test Here
Space-X ITS, ULA ACES	• LOX Cooling system • Propellant Transfer
Bigelow; Space-X	• Deep space integrity test • Life support test
Made In Space, NASA Langley	• Frame structures built in orbit
ULA/Bigelow Cislunar 1000	• Early stages and testbed for surface equipment
Uses	• Microgravity Station • Lunar Gravity Simulator • Mars Gravity Simulator • Earth Gravity Simulator • Earth Departure Vehicle, Cycler

Comparison with Deep Space Gateway

Criteria	DSG	DL1	GL1	GL-2
Deep Space	Yes	Yes	Yes	Yes
Microgravity	Yes	Yes	Yes	Yes
Artificial Gravity			Yes	Yes
Sample Return Time	4 Days	Hours	Hours	Hours
Volume (Cubic M)	139	10	10	330
Crewed	139			330
Mission Cost (USD, M)	8,000*	265	555	1,300
Revisit Cost	1,000			265

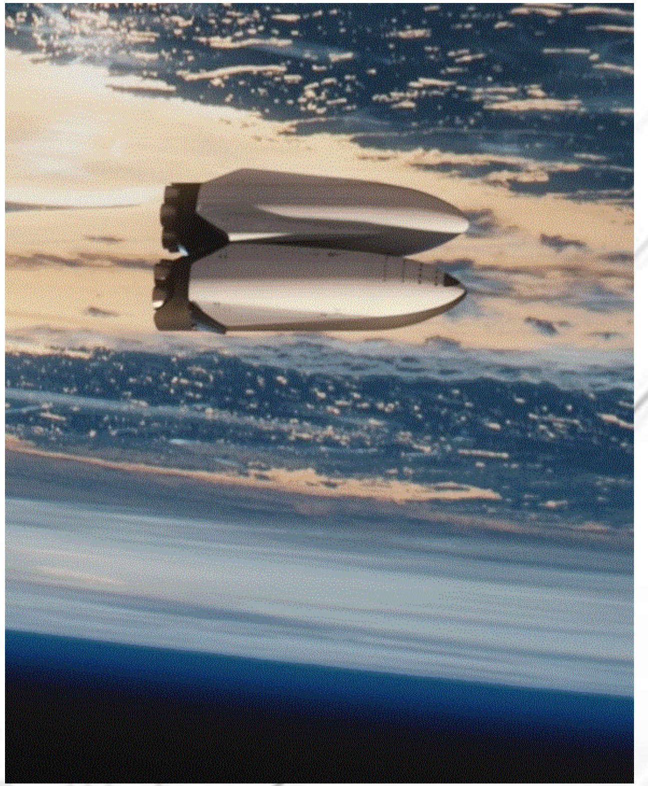
- Does not include the $7.7 billion already spent on SLS or the $11.1 billion already spent on Orion
- We could build DL1, GL1, and four GL-2 (Earth, Mars, Lunar, and Microgravity) and still have $2 billion left over for Experiments, Propellant, Servicing, etc.





Shrinking ITS

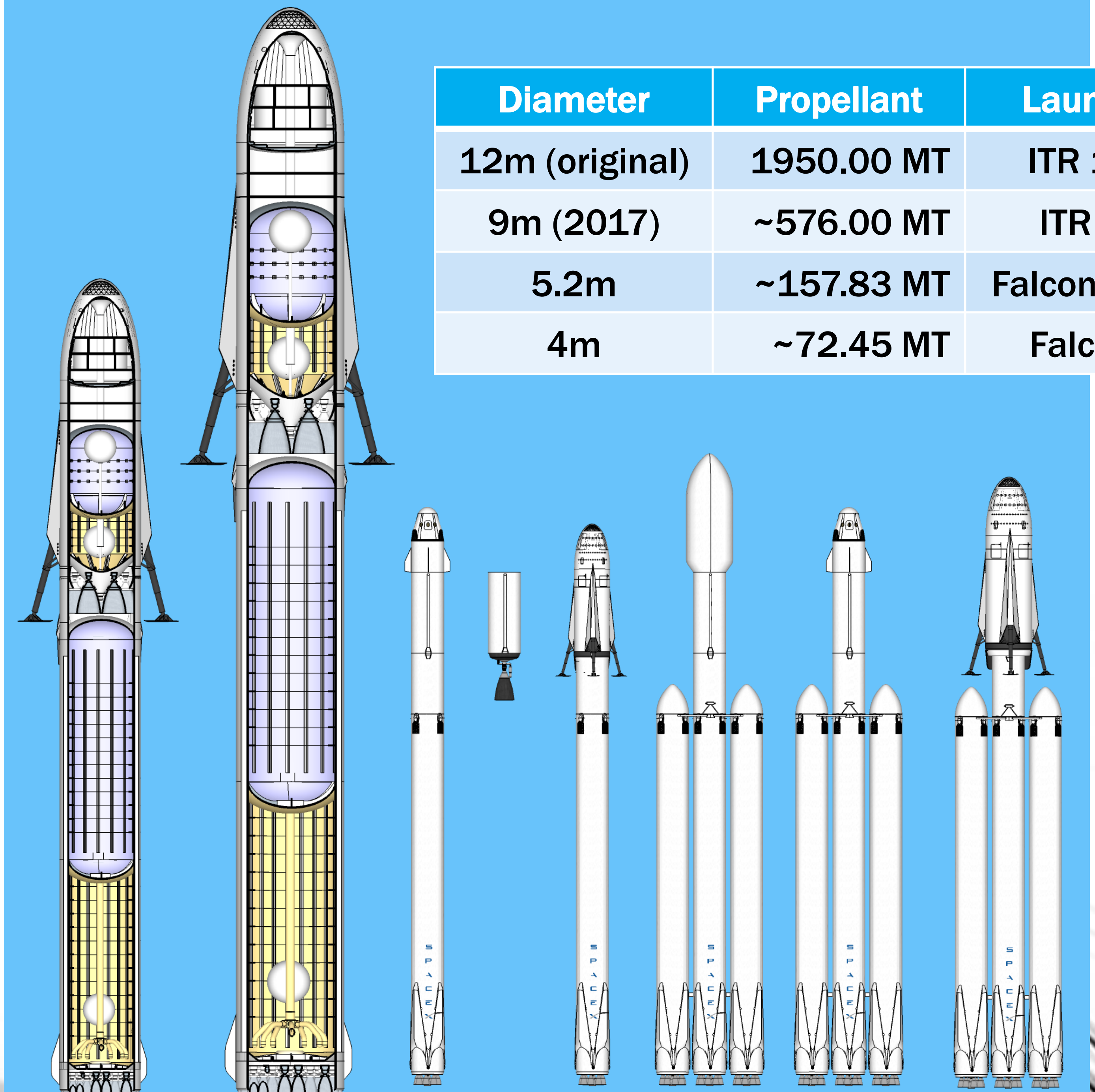
How low can it go and still work?

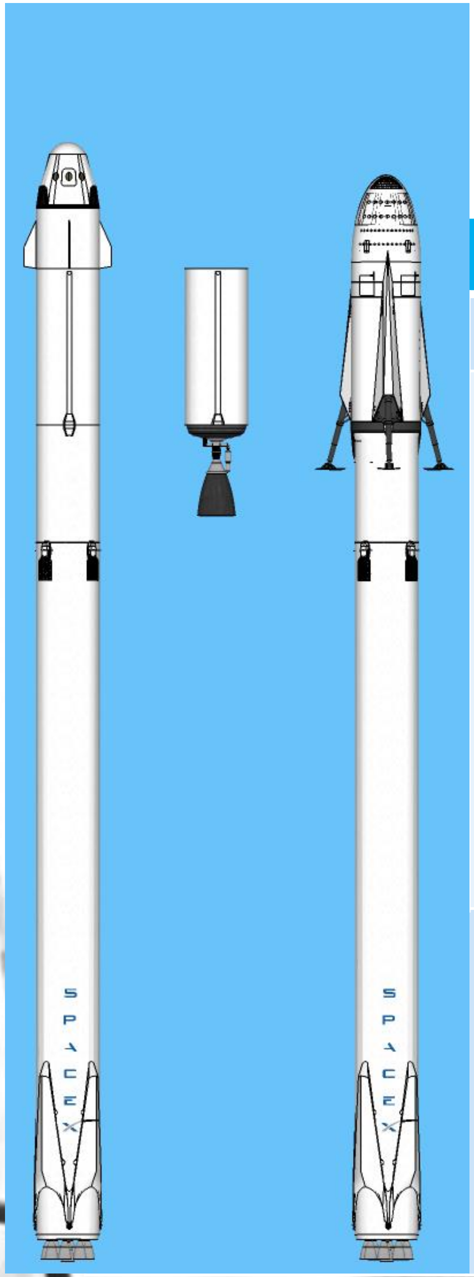


Shrinking the SpaceX Interplanetary Transport Spacecraft

Cutting the ITS Diameter 25 percent decreases the Propellant and Crew Compartment Volume by 70 percent

Diameter	Propellant	Launcher
12m (original)	1950.00 MT	ITR 12m
9m (2017)	~576.00 MT	ITR 9m
5.2m	~157.83 MT	Falcon Heavy
4m	~72.45 MT	Falcon 9

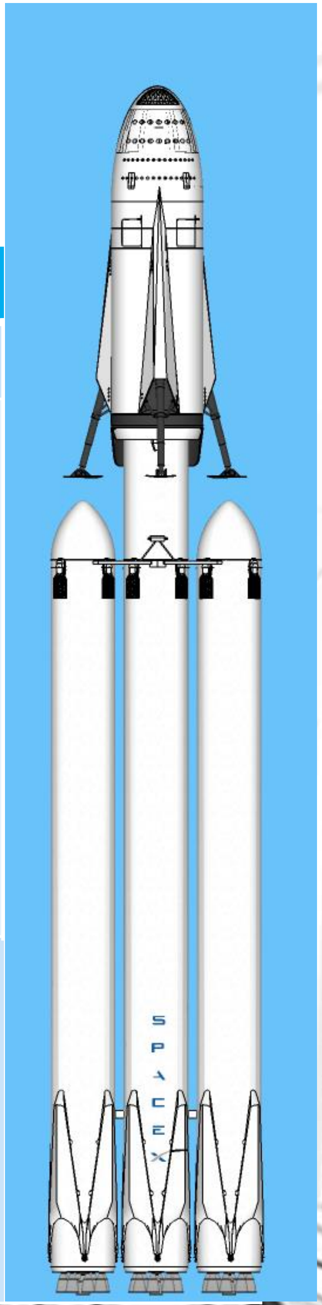




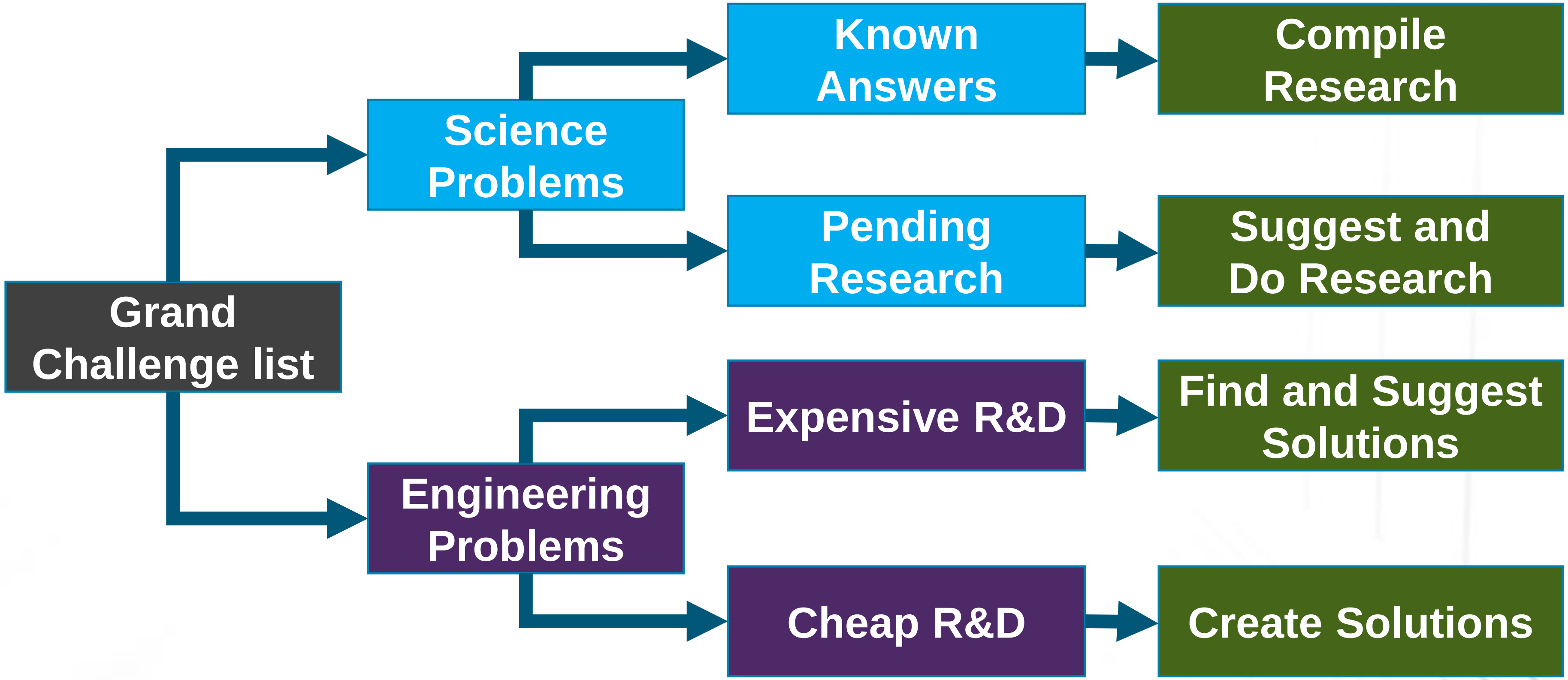
Shrinking the ITS

4 M (F9)	5.2 M (FH)
~72.45 MT Propellant	~157.83 MT Propellant
• Fully-Reusable Dragon/Stage 2 • Can reach ISS, barely • Can weigh 500 kg more without design change, or considerably more with larger tanks. • Refueling on orbit only allows reaching GEO. • No exploration benefit unless fuel tanks expanded.	• Can reach orbit with 30,400 kg dry mass + cargo/crew • If dry mass 13.5 MT or less, can reach Mars if refueled in orbit • Can transfer payloads to GEO and return to LEO

- Landing legs would need to be extended to allow for longer engine, or engine bell shortened and made less efficient.
- Would allow flight tests on Earth (and with larger version, Mars) of biconic atmospheric entry with propulsive landing.



Grand Challenge Breakdown

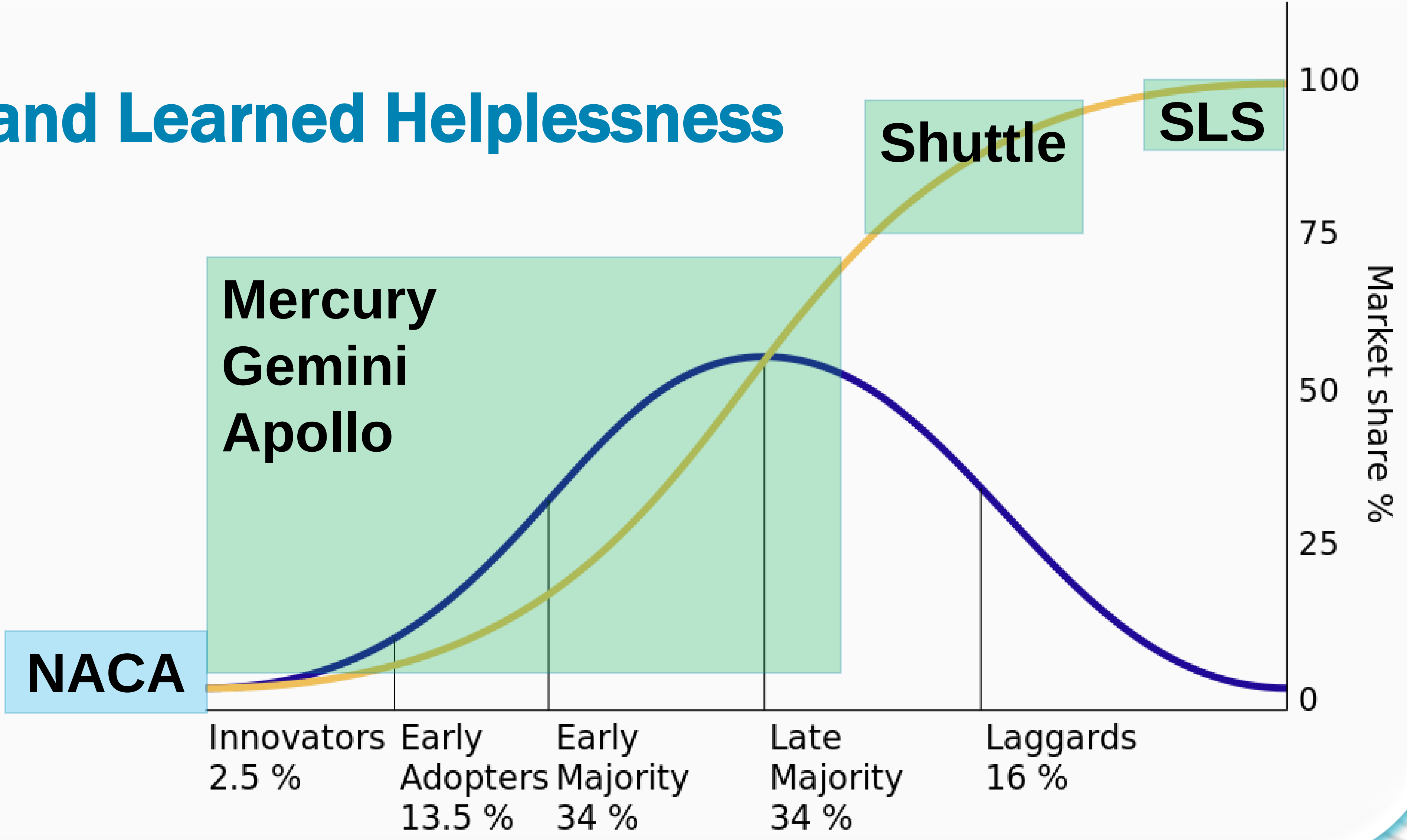


Questions?

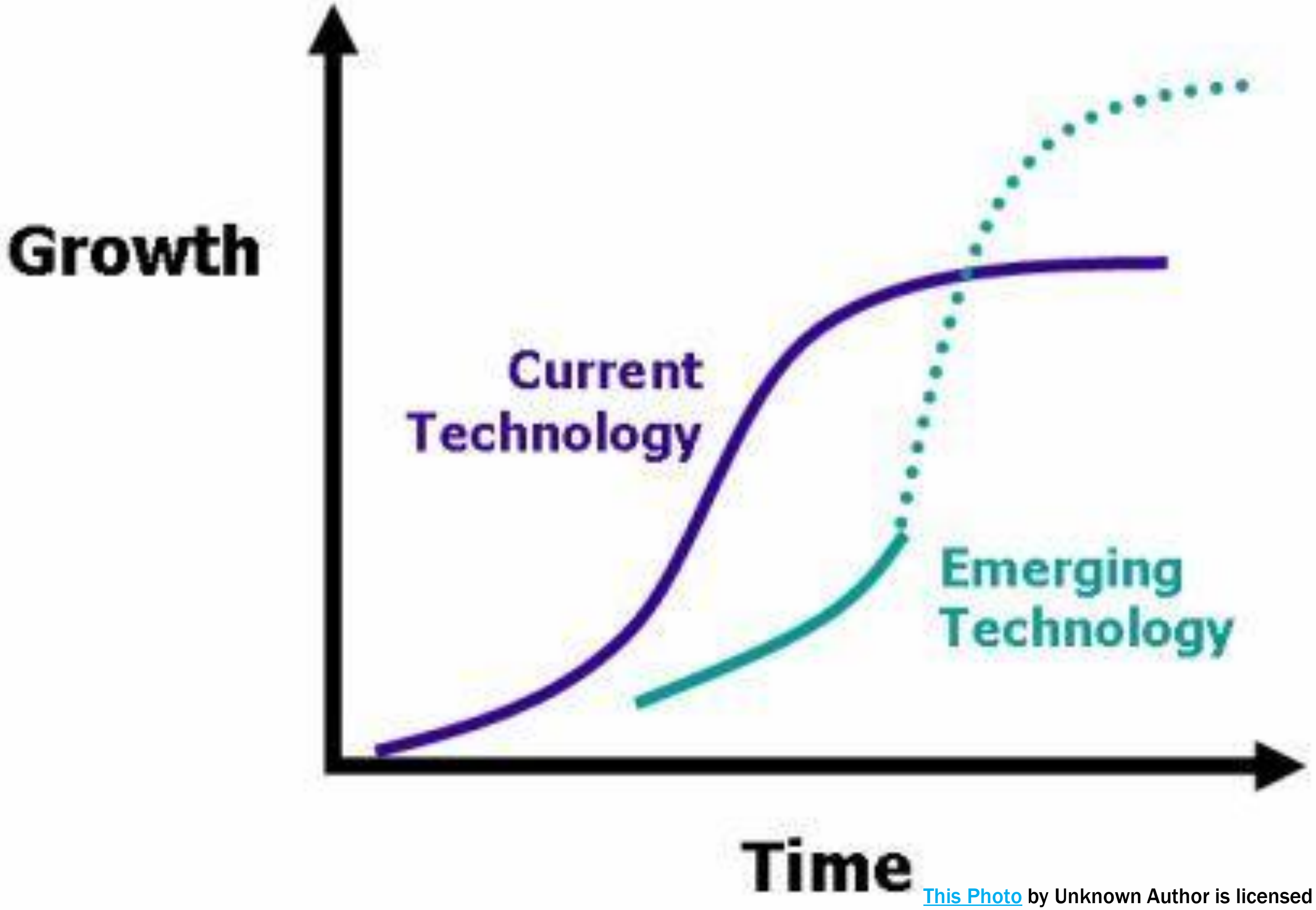
Kent Nebergall

- Macroinvent.com
  - https://www.facebook.com/MacroInvent
- Kent@MacroInvent.com

NASA and Learned Helplessness



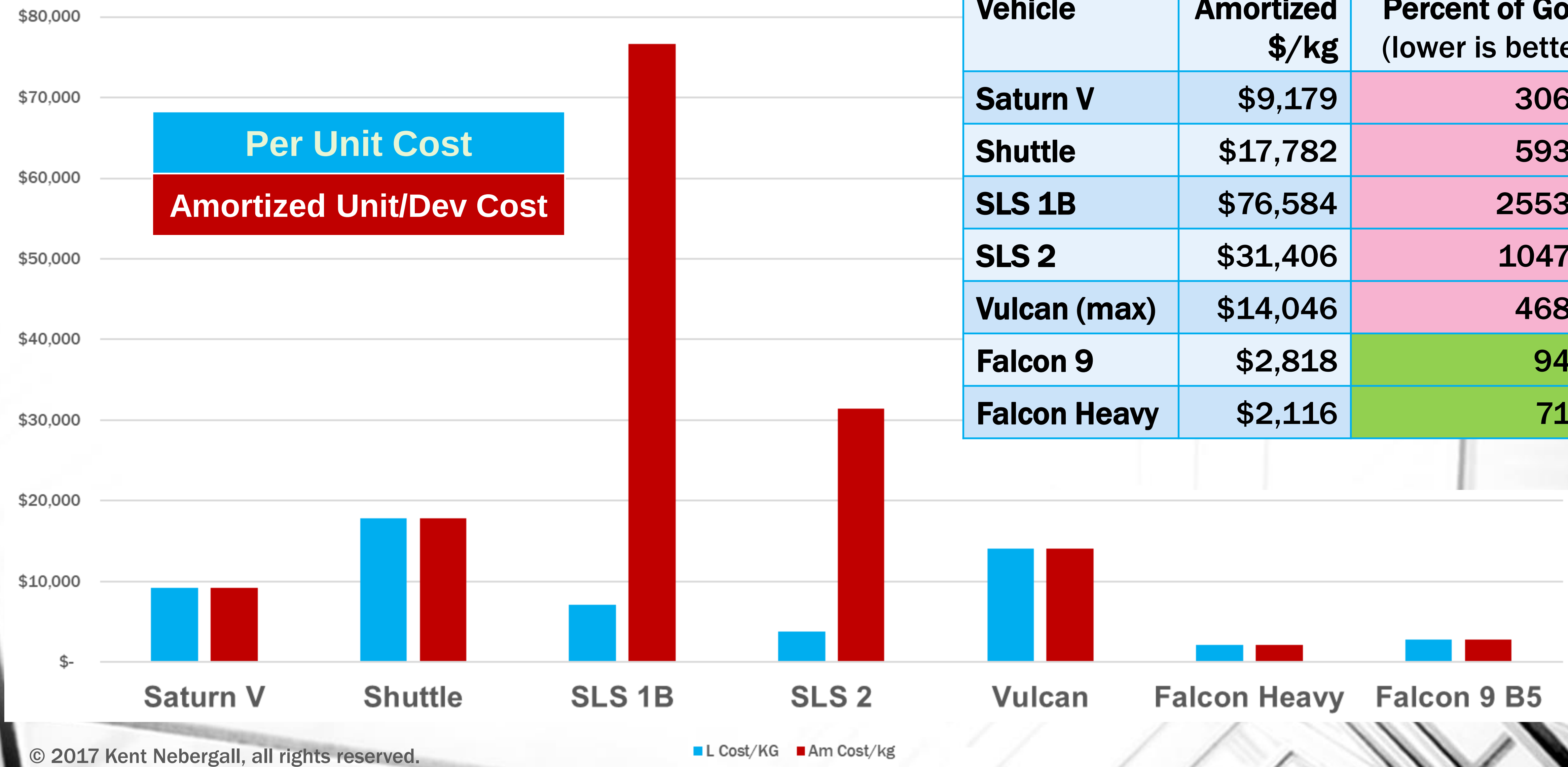
NewSpace Revolution



Space-X
Blue Origin

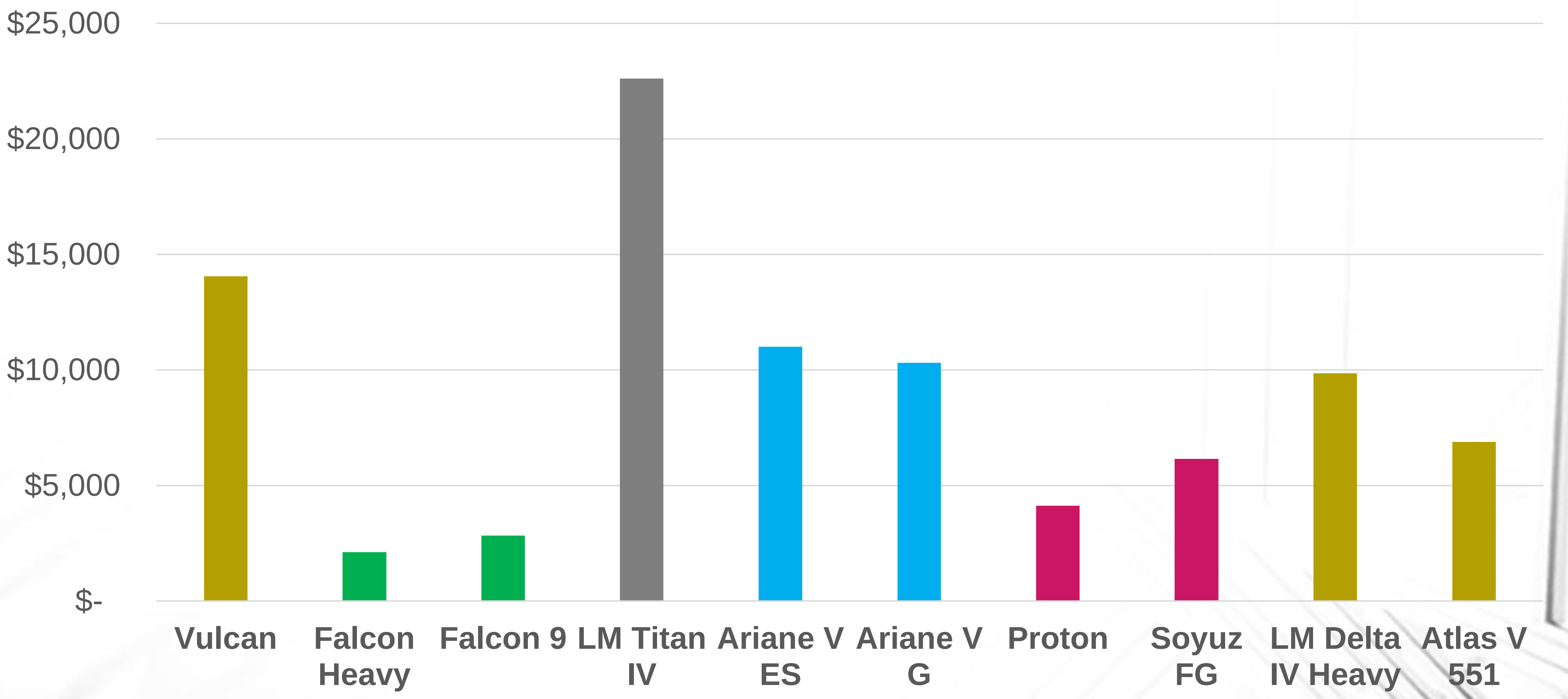
ULA

1.1: Launch Cost per Kilogram

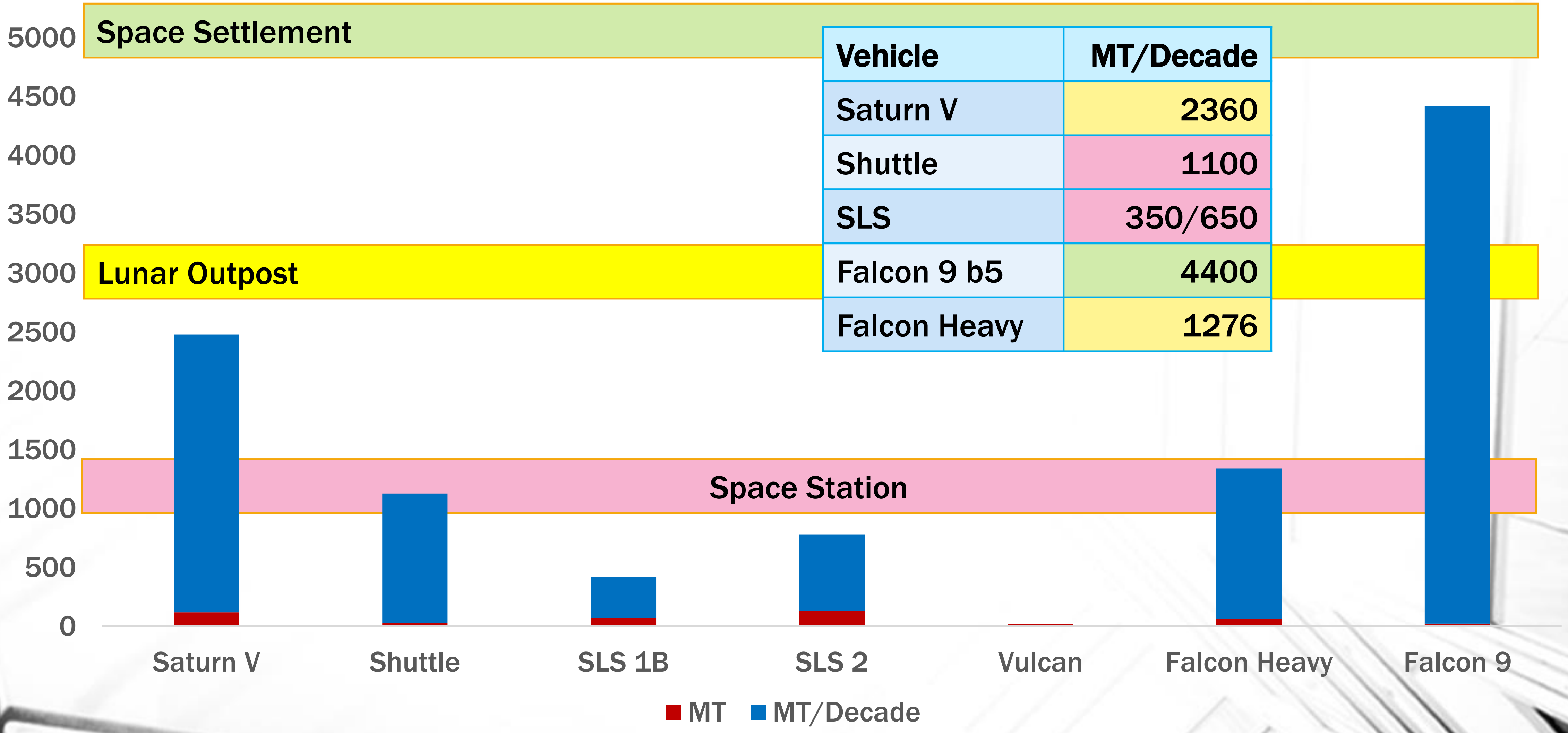


Vehicle	Amortized $/kg	Percent of Goal (lower is better)
Saturn V	$9,179	306%
Shuttle	$17,782	593%
SLS 1B	$76,584	2553%
SLS 2	$31,406	1047%
Vulcan (max)	$14,046	468%
Falcon 9	$2,818	94%
Falcon Heavy	$2,116	71%

Commercial USD/KG (Maximum Payload)



1.2: Launch Capacity/Decade



Vehicle	MT/Decade
Saturn V	2360
Shuttle	1100
SLS	350/650
Falcon 9 b5	4400
Falcon Heavy	1276

NewSpace Phase Challenges and Thresholds

Grand Challenge	Crewed LEO (ISS)	Exploration	Anchor Settlement
Heavy, Cheap Launch	6,000 USD/kg 20 MT/LEO 1000 MT/Decade	3,000 USD/kg 60 MT/LEO 3000 MT/Decade	1,000 USD/kg 200 MT/LEO 5000 MT/Decade
Orbital Refueling	2 MT (Progress)	50 MT	400 MT
Microgravity/Health	6 Months, Microgravity	1 Year, Microgravity 20% Gravity Spin Tether	1 Year, Microgravity 40% Gravity Spin Tether
Radiation	Basic Flare Protection Basic Shelter Available	30 cm Water Equiv. 1 M Flare Shelter	TBD 50 cm Water Equiv.
Life Support	42 % Oxygen 75 % Water	80 % Oxygen 80 % Water	99 % Both, or 95 % plus ISRU
Supply Lifespan	6 Months, 2 MT	3 Years, 10 MT, 4 crew	4 Years, 50 MT, 12 crew Local Basic Food Growth

Exploration Phase Challenges and Thresholds

Grand Challenge	Crewed LEO	Exploration	Anchor Settlement
Mechanical Entropy	30% Crew FTE	10% Crew FTE	1% Crew FTE
Spacesuits	LEO EVA	Lunar EVA, 3-90 Days	Mars EVA, 500 Days
Lunar Surface Operations	N/A	3-9 Person 3-90 Days	12-60 Person, 1-2 Year Rotations
Mars Surface Operations	N/A	4-8 Person, 500 Days	12-60 Person, 3-10 Years
ISRU Fuel/Air/Water	N/A	Prop: 332 MT Water: 9 MT Oxygen: 7 MT	Prop: 2000 MT Water: 55 MT Oxygen: 42 MT
Earth Return	500 kg, 3 Crew, LEO Entry	500 kg, 3-6 Crew, Deep Space Entry, 180 Day Return Flight	12-50 People, Deep Space Entry, 180 Day Return Flight

Where Cronyism Comes From

Government (Source)	Crony/Political Actors	Object Response
Needs a new technical capacity for a goal	Receives massive investment to develop that technology	Public celebrates and is inspired by the new innovation.
Needs increased capacity in same range	Receives continued funding to push technical envelope	Rival governments build similar systems using similar methods.
Programs become self-driving constituencies	In 2-4 iterations, structure grows large enough to "create it's own weather"	System becomes a goal, not a means to a goal.
Public begins to notice the system is overpriced	Products end up overpriced to support the bloat (cost plus), not the mission.	Competitors realize they can make better systems for less money.
Vested political interests continue funding overpriced systems	Political actors use clout to lobby for regulation to cut out competition, arguing that it will "lower costs".	Corporate competitors cut costs and scale systems for efficiency, and move B list payload.

Killing the Feedback, Boosting the Volume

Government Role	Action	Restriction
Primary Research	Expand the definition of Feasible	Do not spend more than ~10 percent total
Needs a new technical capacity	Invest in new technology that is in the proper affordable/feasible zone. • Just beyond commercially self-funded • Just within fully-doable driven by primary research	Projects must have… • Beginning, middle, and end • Measurable results • Enable next wave technologies • Fixed price contracts or competitive "fly off" contracts to winners
Commercialize the last wave	• Use to expand information, trade, science, education. • Offer lab space to new competitors	• Demonstrate GAAP measurable value from previous wave • Tax revenue from commercialization of previous wave.
Seed for Next Wave	• Invest in engineering education, basic research prior to wave. • Repeat the loop.	• Restrict spending to match revenue. • As more waves come in, more investment possible.