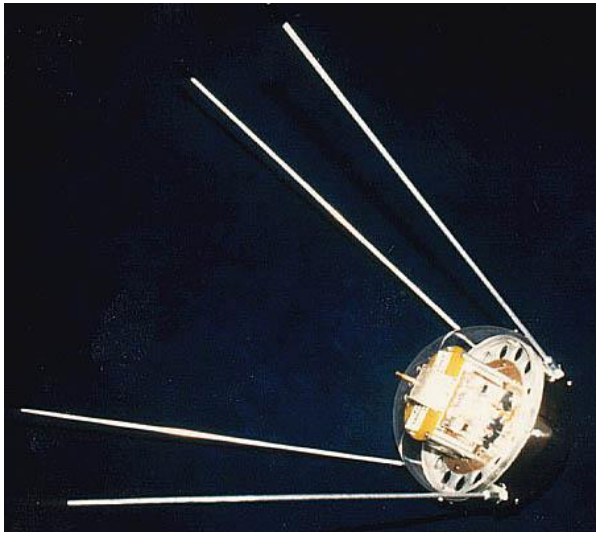
ASTRONOMY
EXPLORING SPACE & TIME

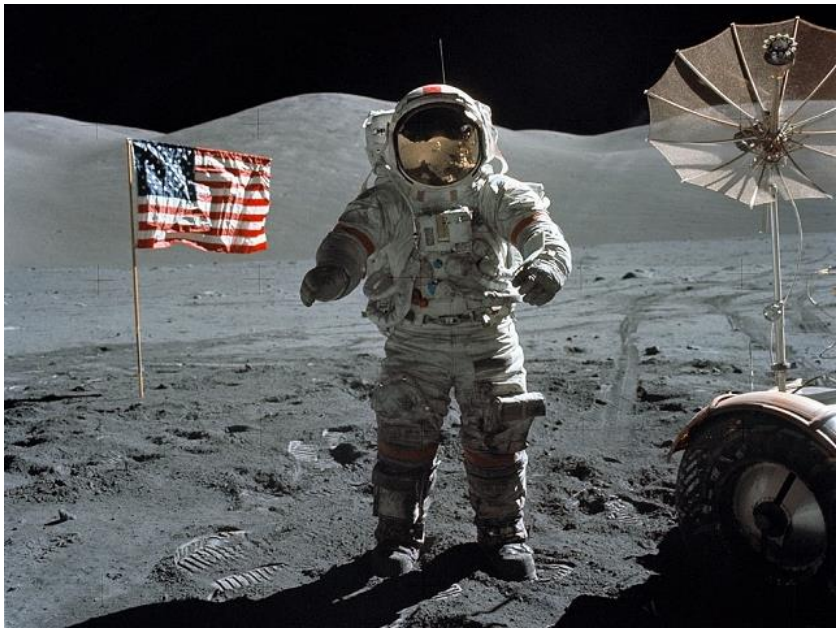
Space Travel

Mastering Space



The space age is a little over 50 years old. The activity has mostly been the work of 2 countries, often driven by military or geopolitical motives. NASA is the exception.

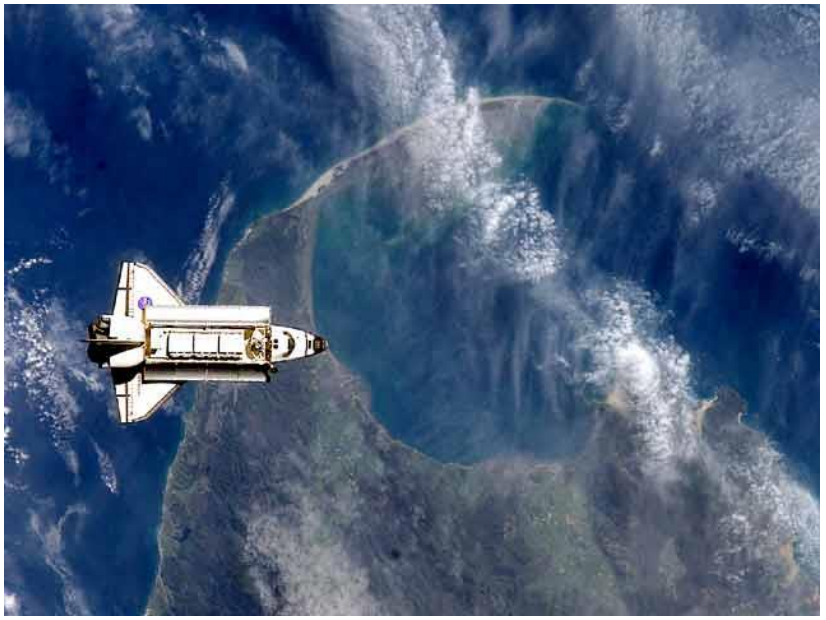
About 300 people have been in orbit. A dozen have set foot on the Moon and it is ~40 years since we have been there. Space travel is very exciting and very dangerous.



It's important to realize the space program is still in its very early phases…

A Cloudy Vision

The Space Shuttle represents 40 year old technology. Two of five has been lost, and the catastrophic failure rate is 1 in 50. The military gave up on it and developed its own launch vehicle and the telecommunications industry uses rockets from Europe and China. Per launch cost is ~$500 million. The plan for a successor is very unclear.



The space station was supposed to cost $8 billion back in 1984. It is heading for $50 billion yet it has few users, though it is the best way station for deep space.

Yet there is also an opportunity in engineers and entrepreneurs with expertise, vision, ambition.

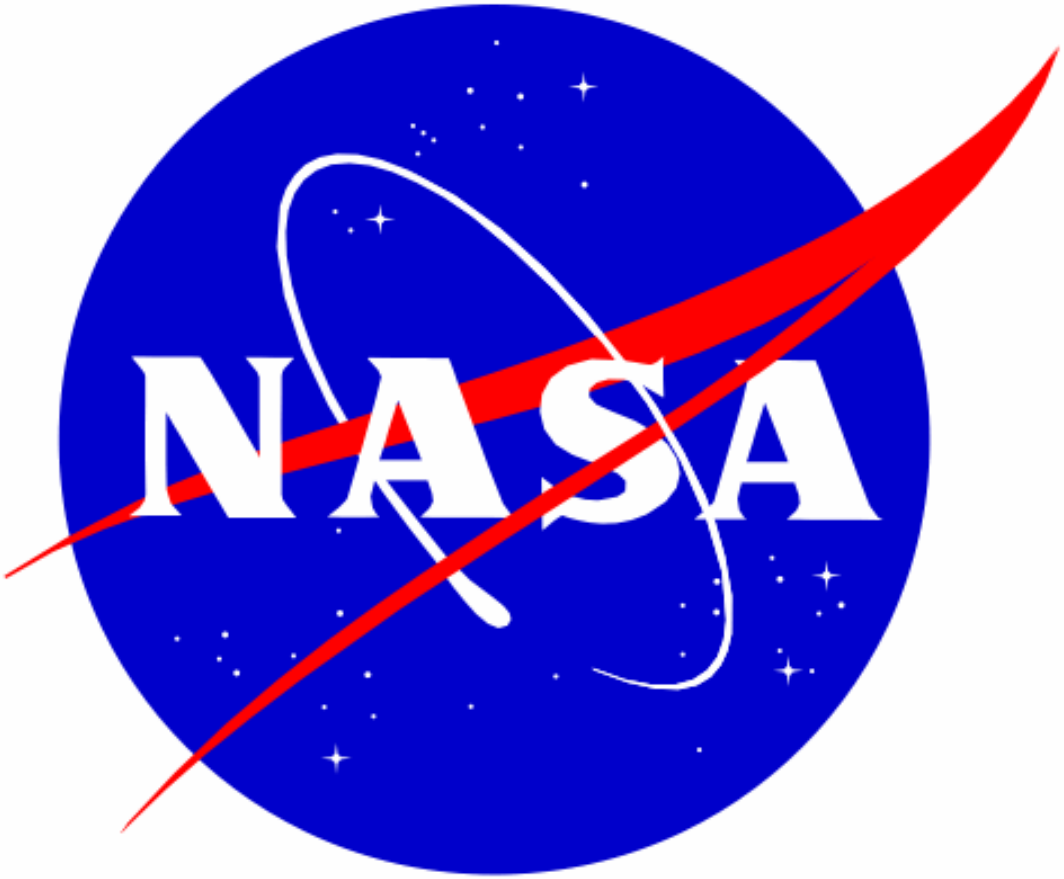
Shuttle Redux

Shuttle Redux

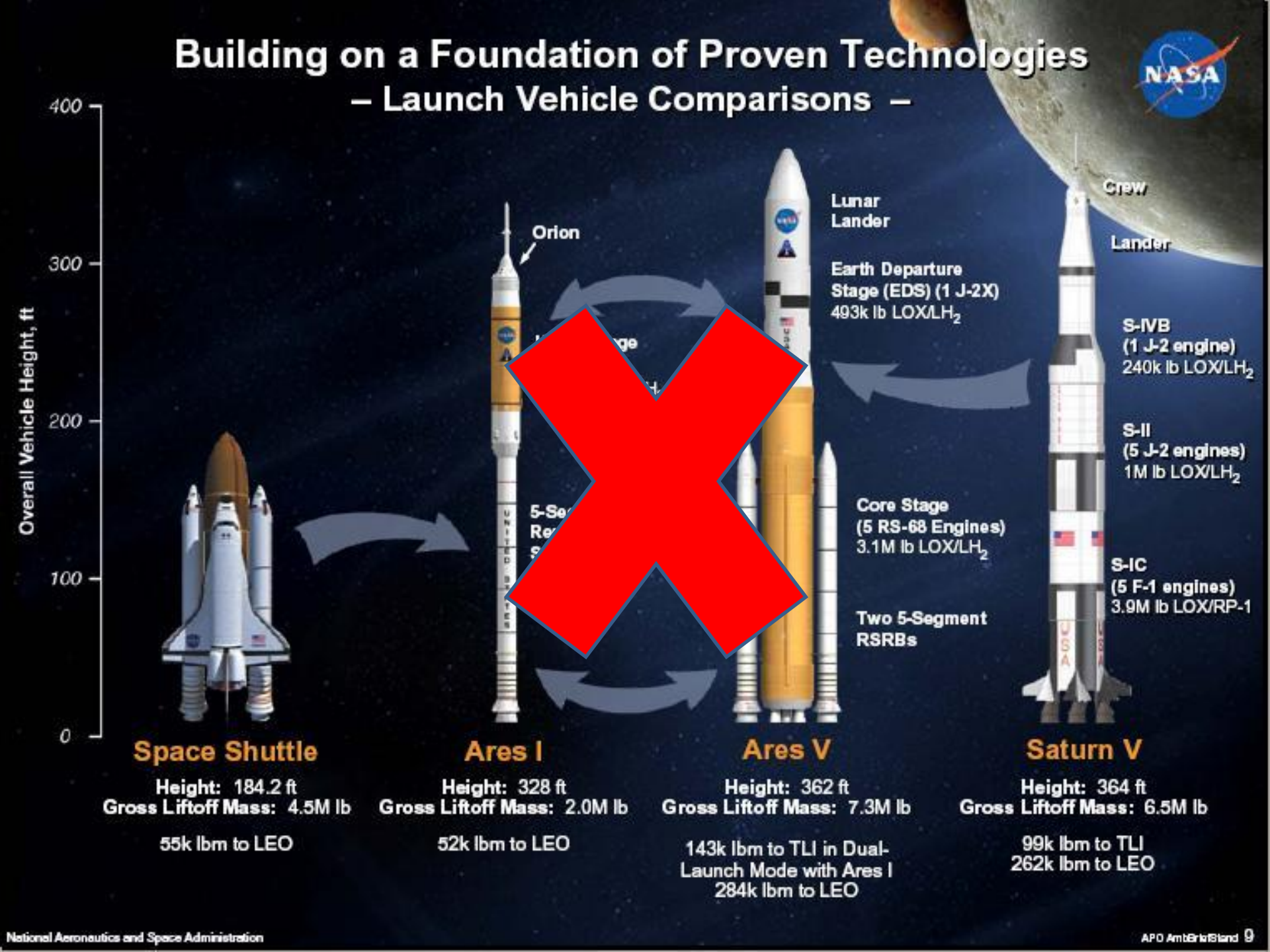
New Launch Vehicles

New Launch Vehicles

The Role of NASA



Building on a Foundation of Proven Technologies
– Launch Vehicle Comparisons –



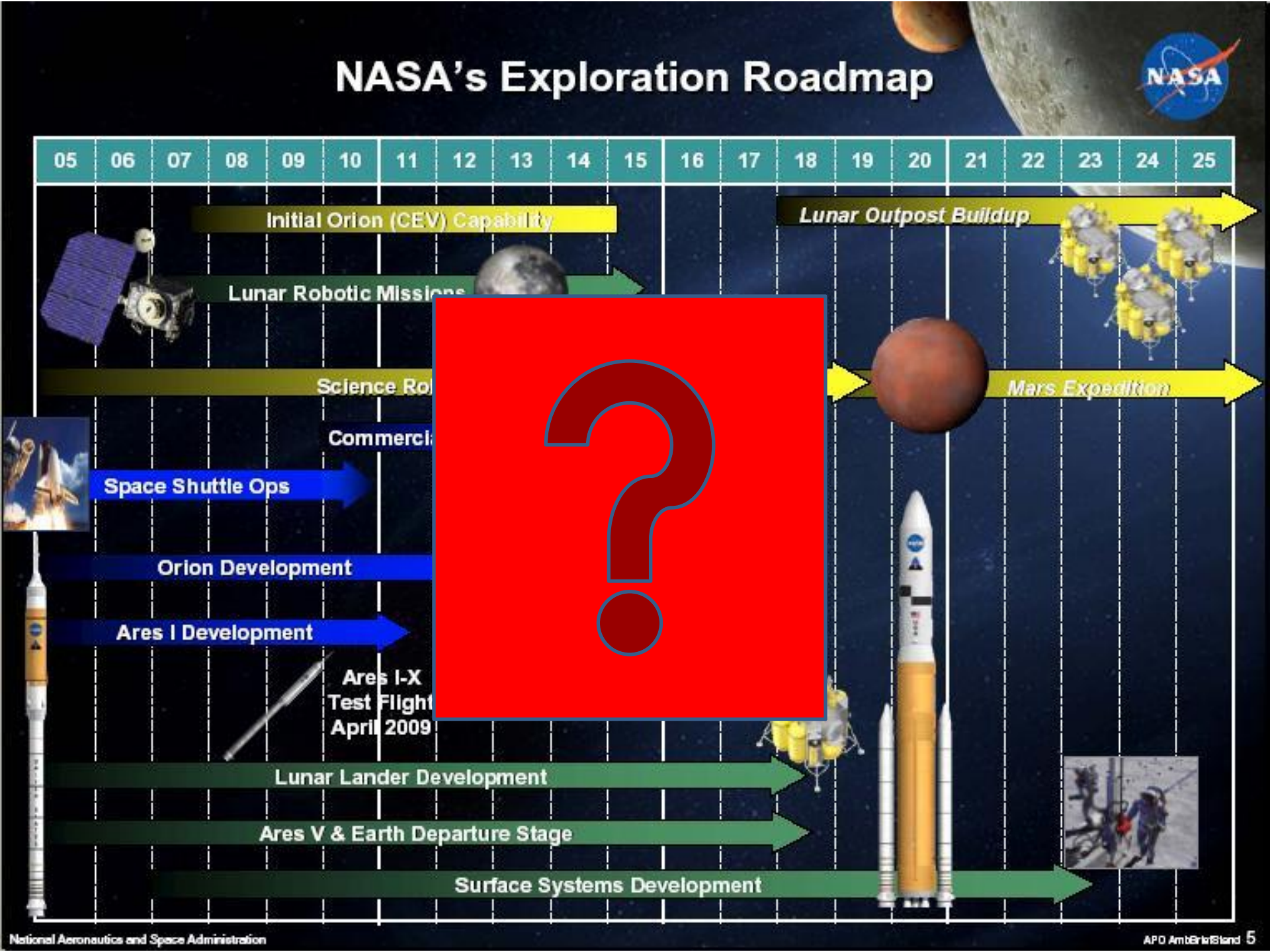
Space Shuttle
Height: 184.2 ft
Gross Liftoff Mass: 4.5M lb
55k lbm to LEO

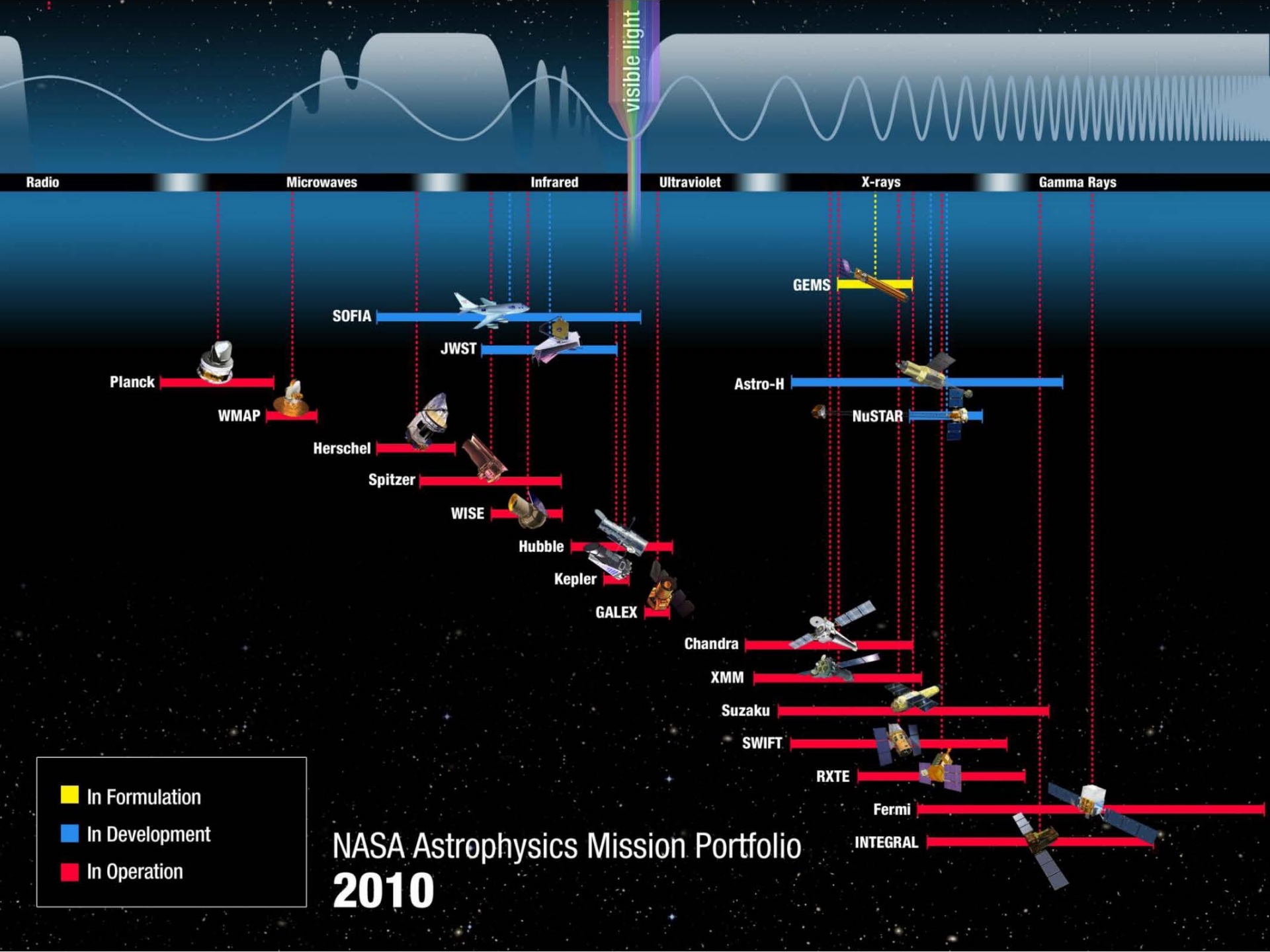
Ares I
Height: 328 ft
Gross Liftoff Mass: 2.0M lb
52k lbm to LEO

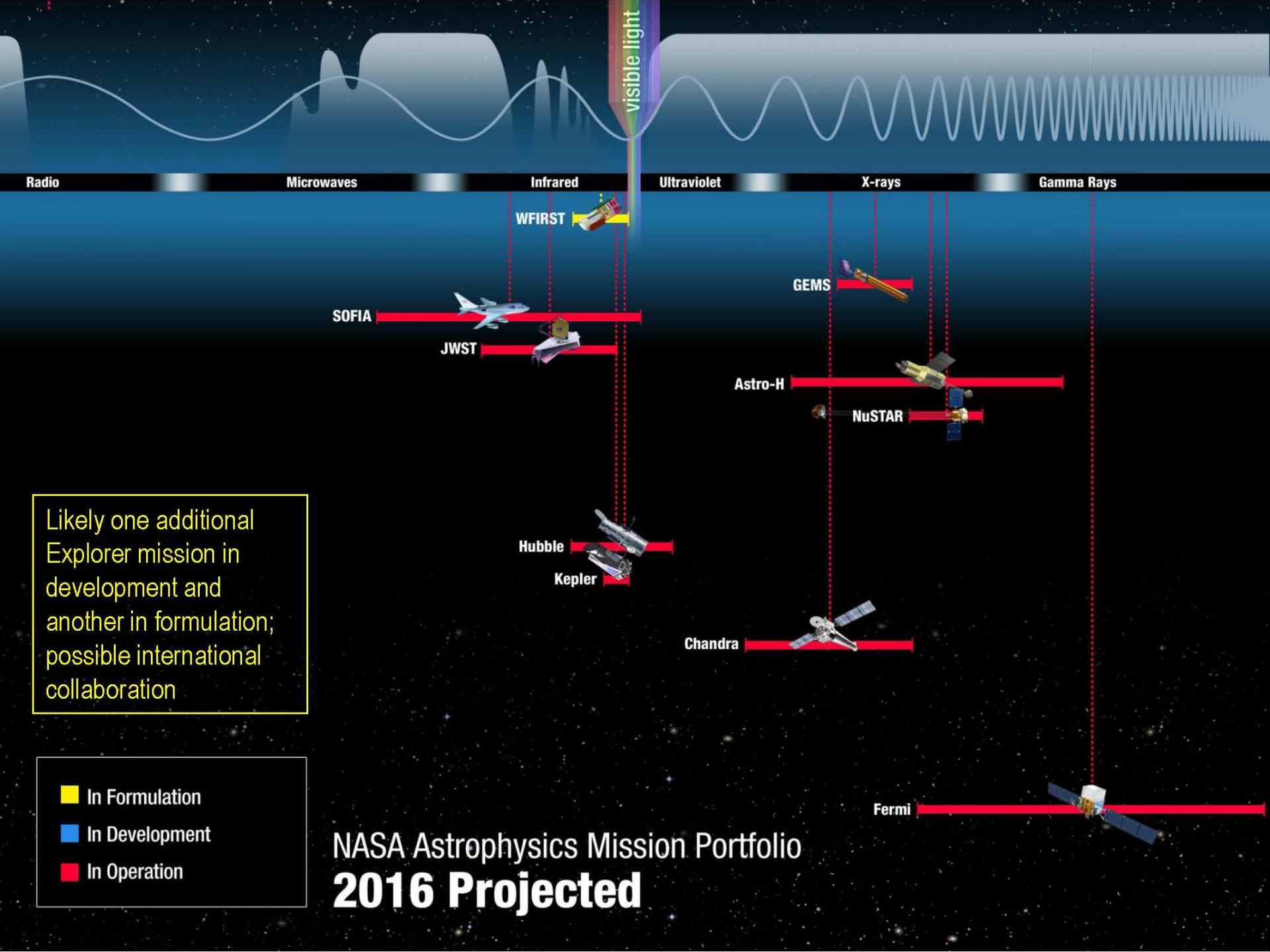
Ares V
Height: 362 ft
Gross Liftoff Mass: 7.3M lb
143k lbm to TLI in Dual-Launch Mode with Ares I
284k lbm to LEO

Saturn V
Height: 364 ft
Gross Liftoff Mass: 6.5M lb
99k lbm to TLI
262k lbm to LEO

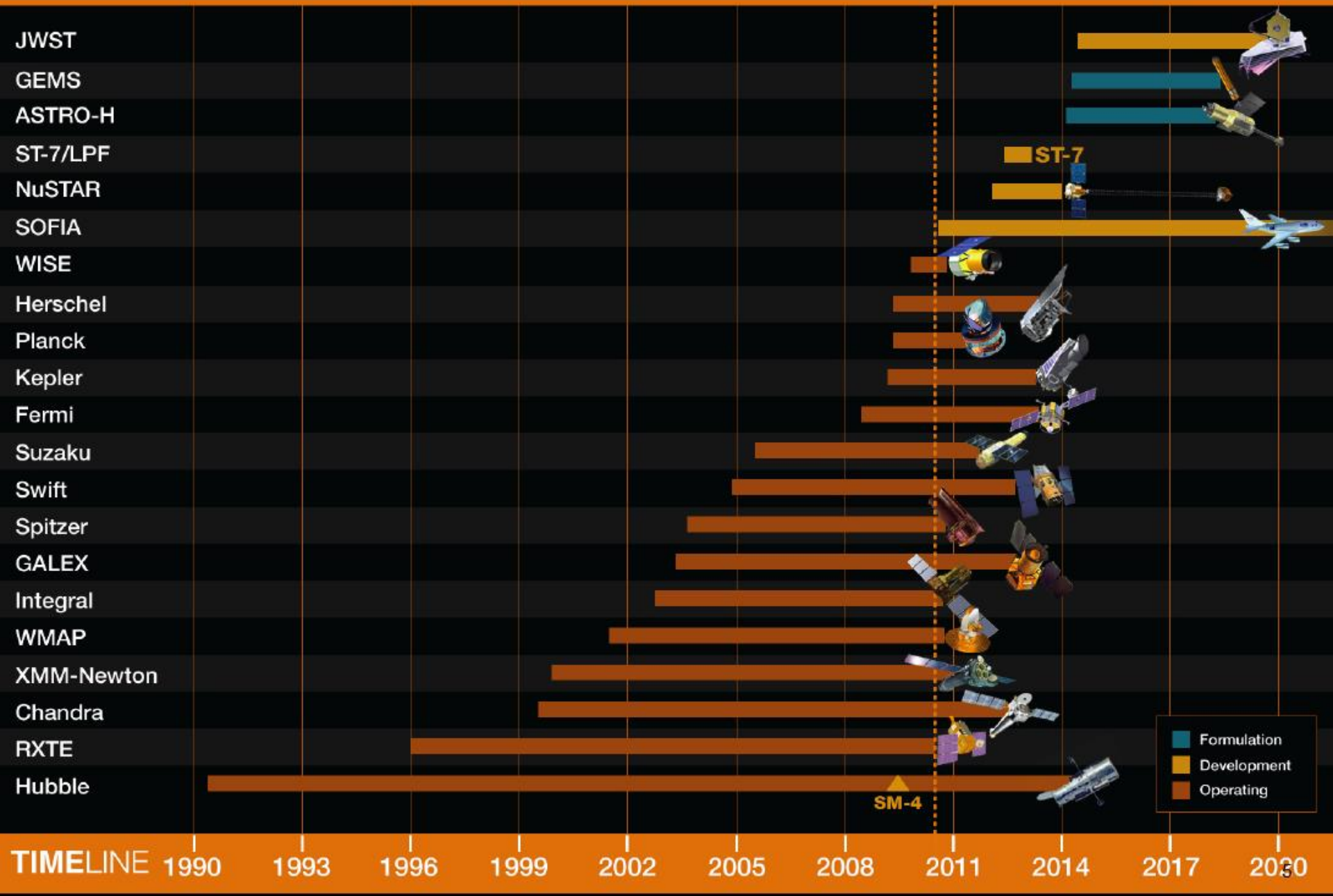
NASA's Exploration Roadmap




visible light
Radio
Microwaves
Infrared
Ultraviolet
X-rays
Gamma Rays
GEMS
SOFIA
JWST
Planck
WMAP
Astro-H
NuSTAR
Herschel
Spitzer
WISE
Hubble
Kepler
GALEX
Chandra
XMM
Suzaku
SWIFT
RXTE
Fermi
INTEGRAL
In Formulation
In Development
In Operation
NASA Astrophysics Mission Portfolio
2010

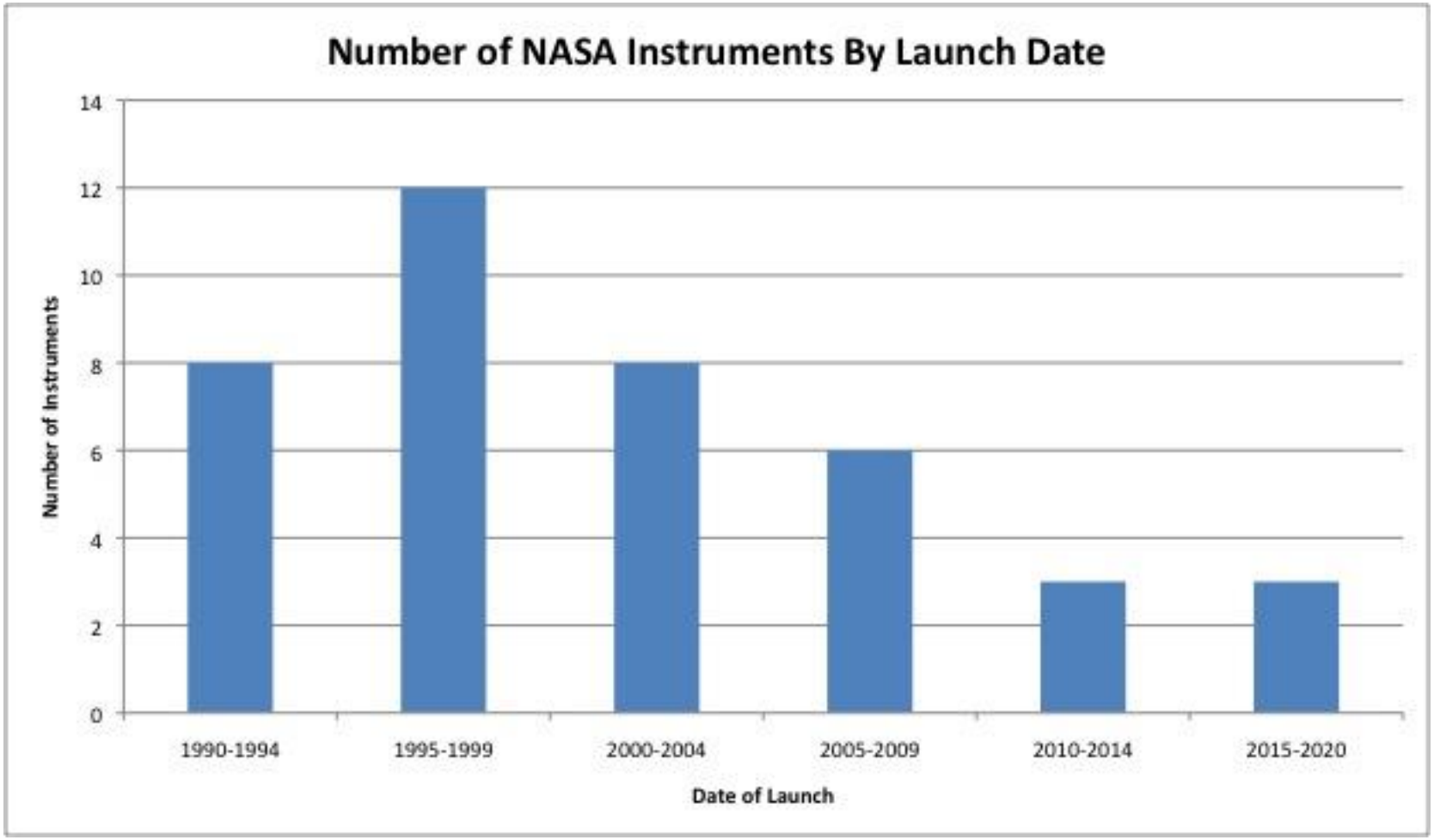

visible light
Radio
Microwaves
Infrared
Ultraviolet
X-rays
Gamma Rays
WFIRST
GEMS
SOFIA
JWST
Astro-H
NuSTAR
Hubble
Kepler
Chandra
Fermi
Likely one additional Explorer mission in development and another in formulation; possible international collaboration
In Formulation
In Development
In Operation
NASA Astrophysics Mission Portfolio
2016 Projected

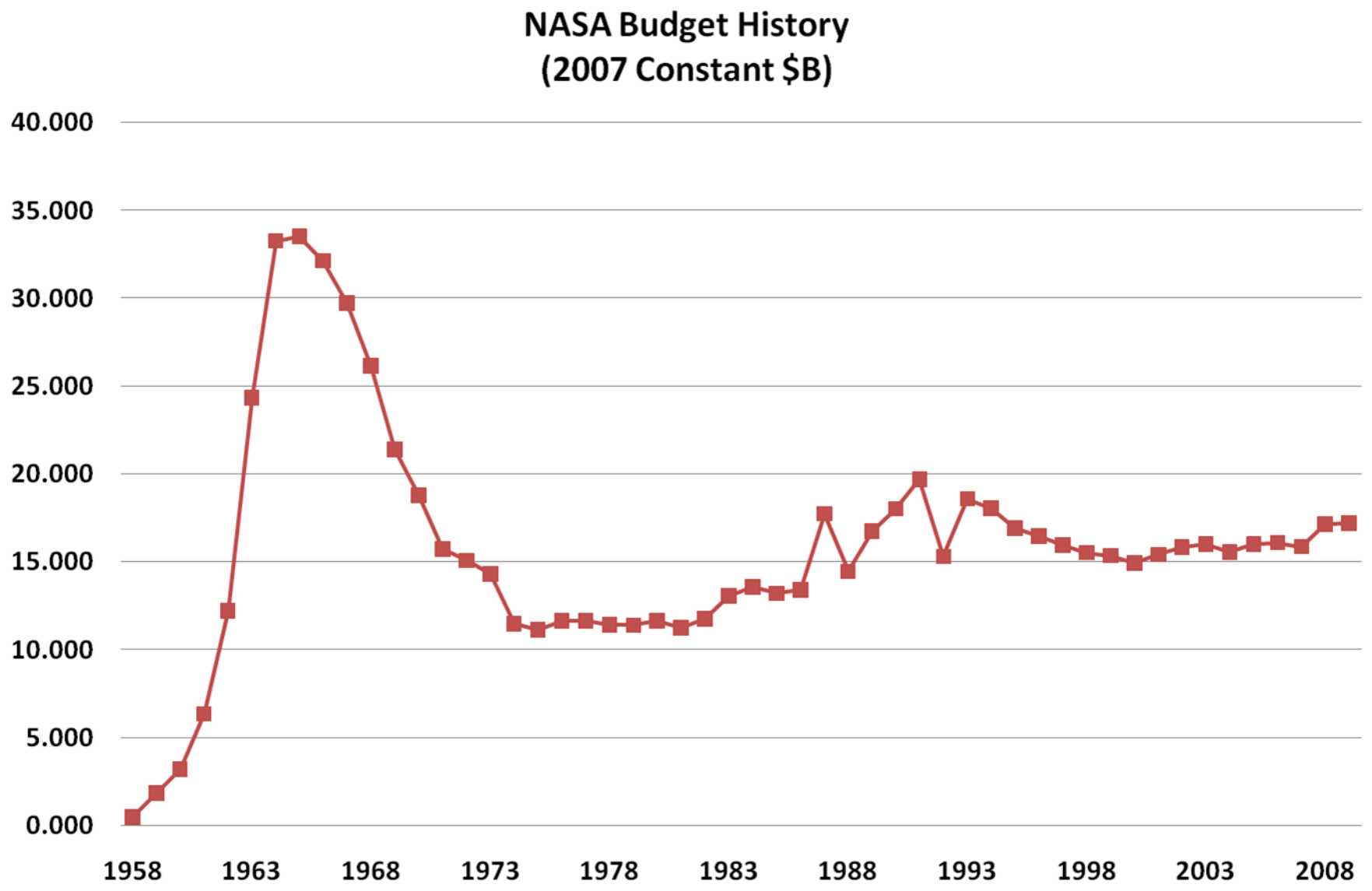
Astrophysics Missions timeline

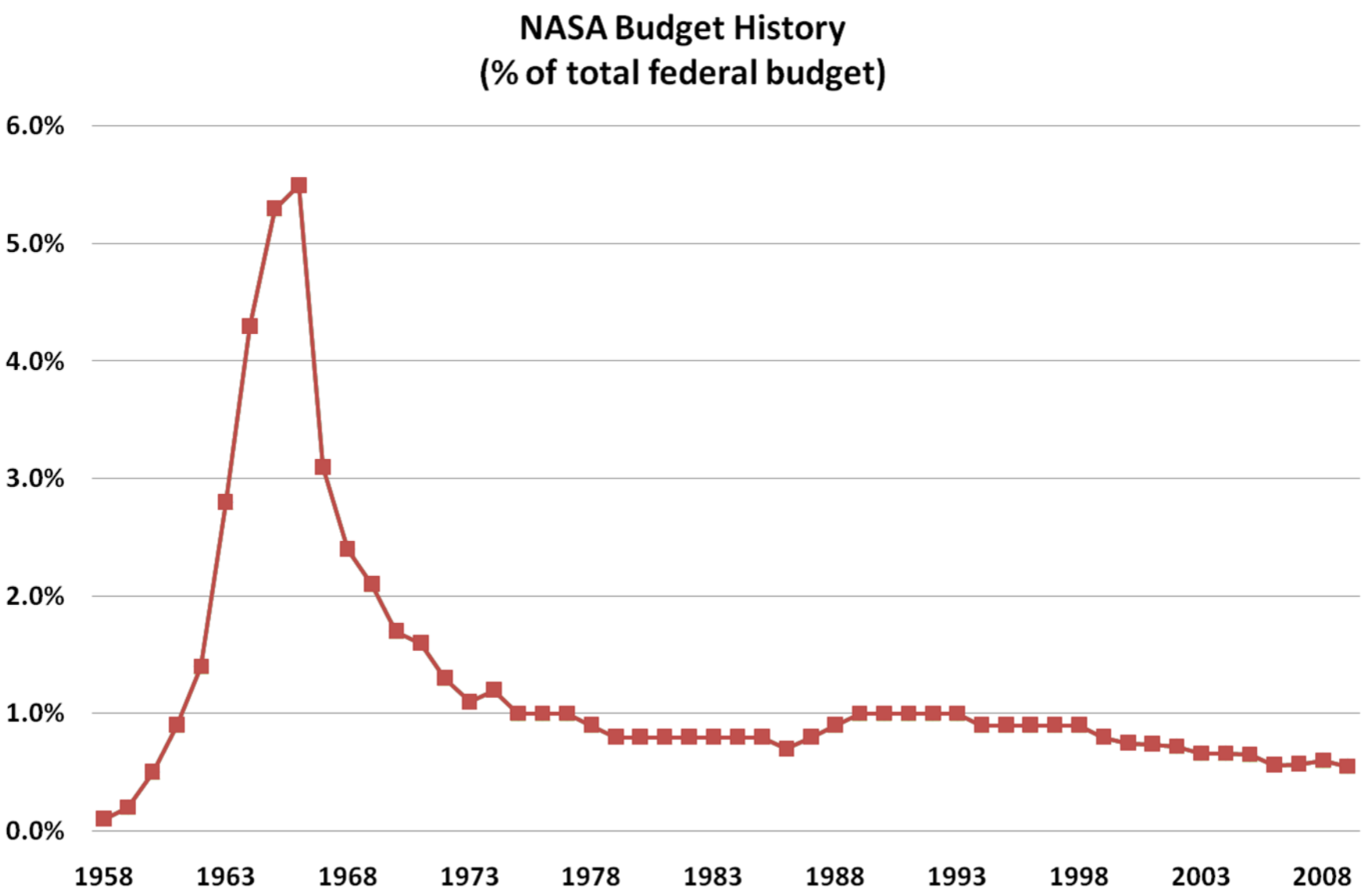


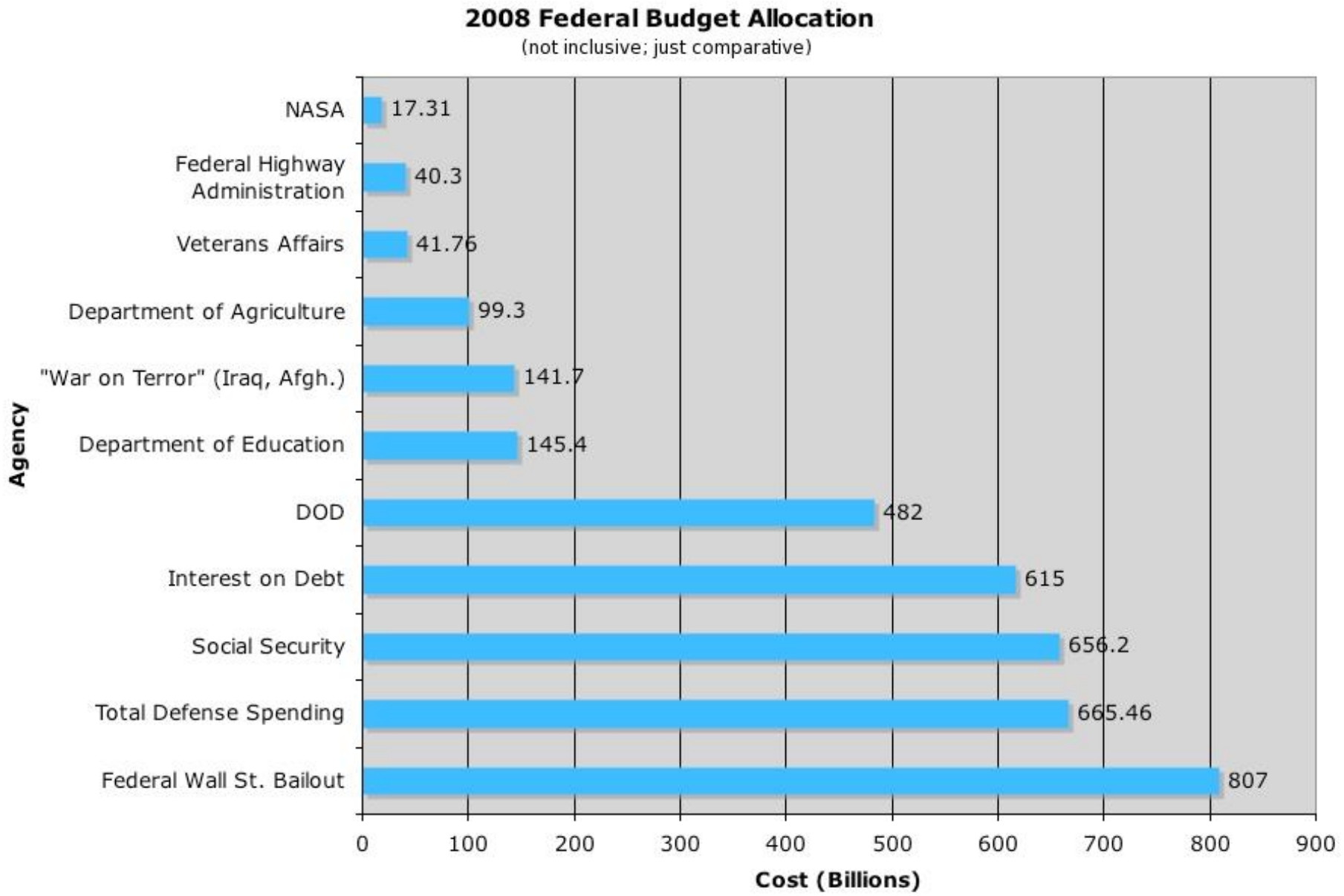
End of the Golden Age?

Constrained budgets and the escalating cost and technical difficulty of science missions makes the future uncertain.

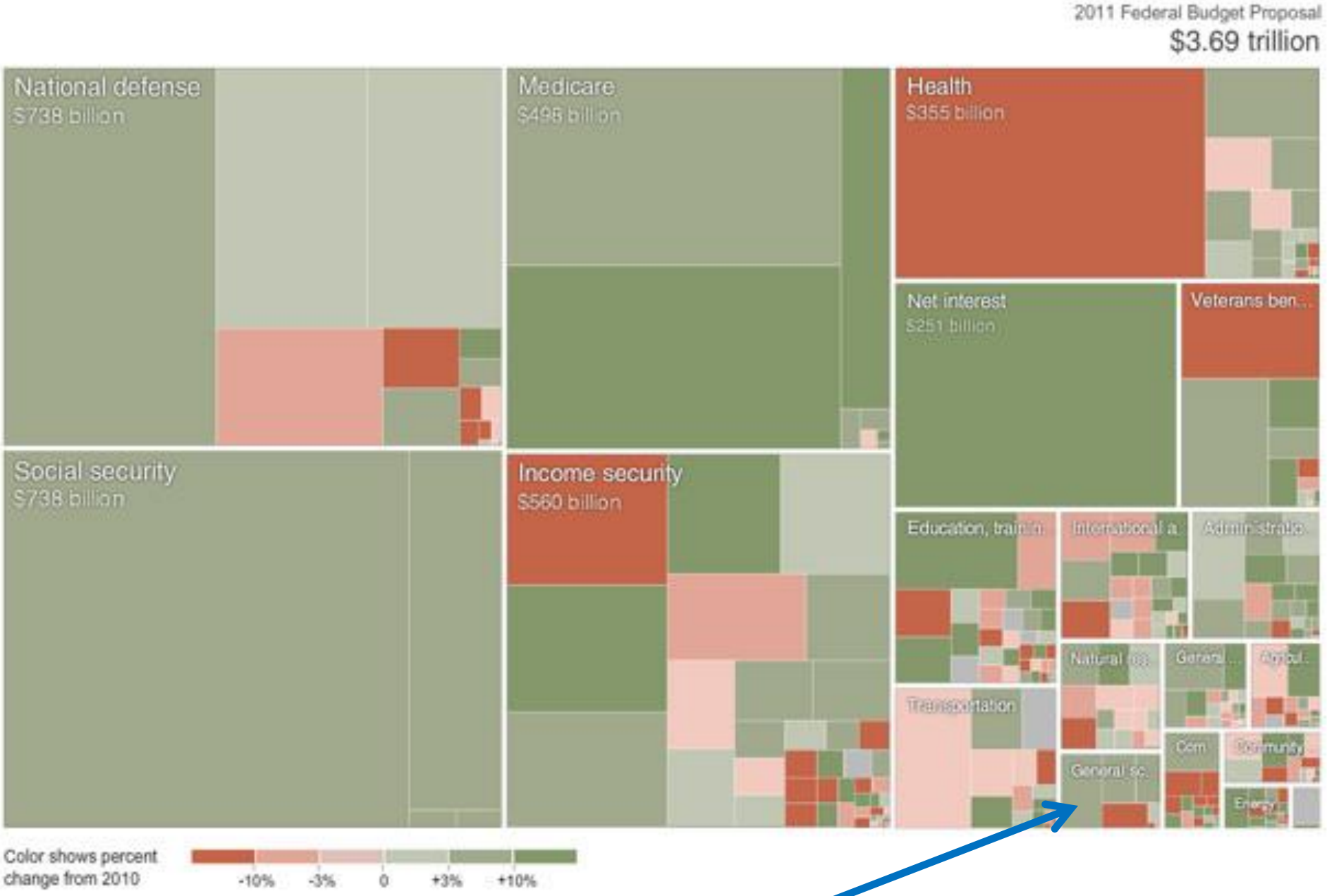



NASA Budget History
(2007 Constant $B)
40.000
35.000
30.000
25.000
20.000
15.000
10.000
5.000
0.000
1958
1963
1968
1973
1978
1983
1988
1993
1998
2003
2008


NASA Budget History
(% of total federal budget)
6.0%
5.0%
4.0%
3.0%
2.0%
1.0%
0.0%
1958
1963
1968
1973
1978
1983
1988
1993
1998
2003
2008

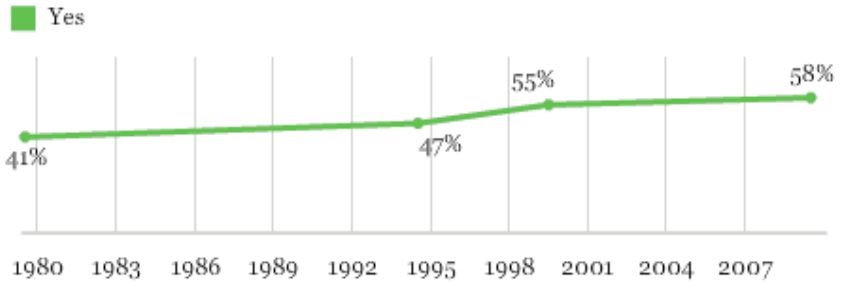


* "Total Defense Spending" includes DOD, VA and War on Terror monies
* Interest on debt does not include interest on bailout debt
* This chart compares a few agencies and excludes many others.


2011 Federal Budget Proposal
$3.69 trillion
National defense
$738 billion
Medicare
$495 billion
Health
$355 billion
Net interest
$251 billion
Veterans ben...
Social security
$738 billion
Income security
$560 billion
Education, train'n
Transportation
Color shows percent change from 2010
-10%
-3%
0
+3%
+10%
NASA Lives Here

Public Support

It is now 40 years since the United States first landed men on the moon. Do you think the space program has brought enough benefits to this country to justify its costs, or don't you think so?

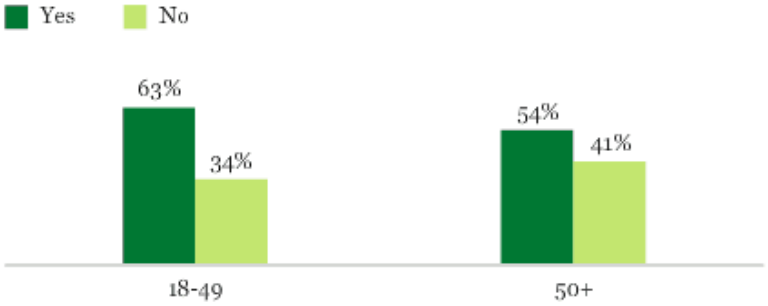


1979 poll conducted by NBC News/Associated Press

GALLUP POLL

It is now 40 years since the United States first landed men on the moon. Do you think the space program has brought enough benefits to this country to justify its costs, or don't you think so?

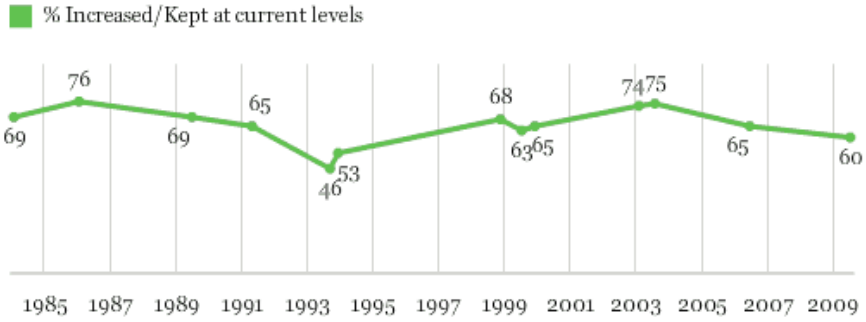
By age



July 10-12, 2009

GALLUP POLL

Do you think spending on the U.S. space program should be increased, kept at the present level, reduced, or ended altogether?



GALLUP POLL

How would you rate the job being done by NASA -- the U.S. space agency? Would you say it is doing an excellent, good, only fair, or poor job?

GALLUP POLL

Last year, even during a recession, support for NASA remained strong

Commercial Sector

Private Sector

Billionaire Dennis Tito paid $20 million to ride a Russian Soyuz spacecraft for a week's vacation to the Space Station. Charles Simonyi went twice (and space-walked the second time) for a cool $35 million.

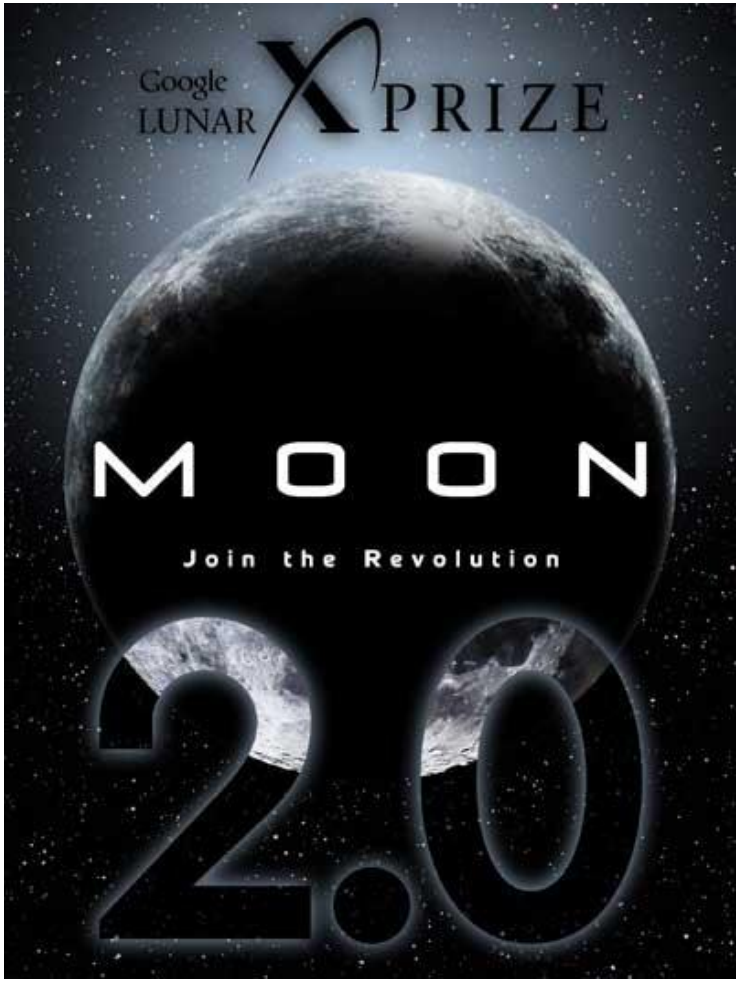
Inspired by the $25,000 prize won by Lindbergh in 1927, the $10 million X-prize was won by Burt Rutan for a repeated sub-orbital flight reaching 100 km. Google now has a Moon prize.

Billionaire entrepreneur Richard Branson (Virgin Group) partnered with Burt Rutan to form The Spaceship Company. There are 11 private space outfits worldwide.

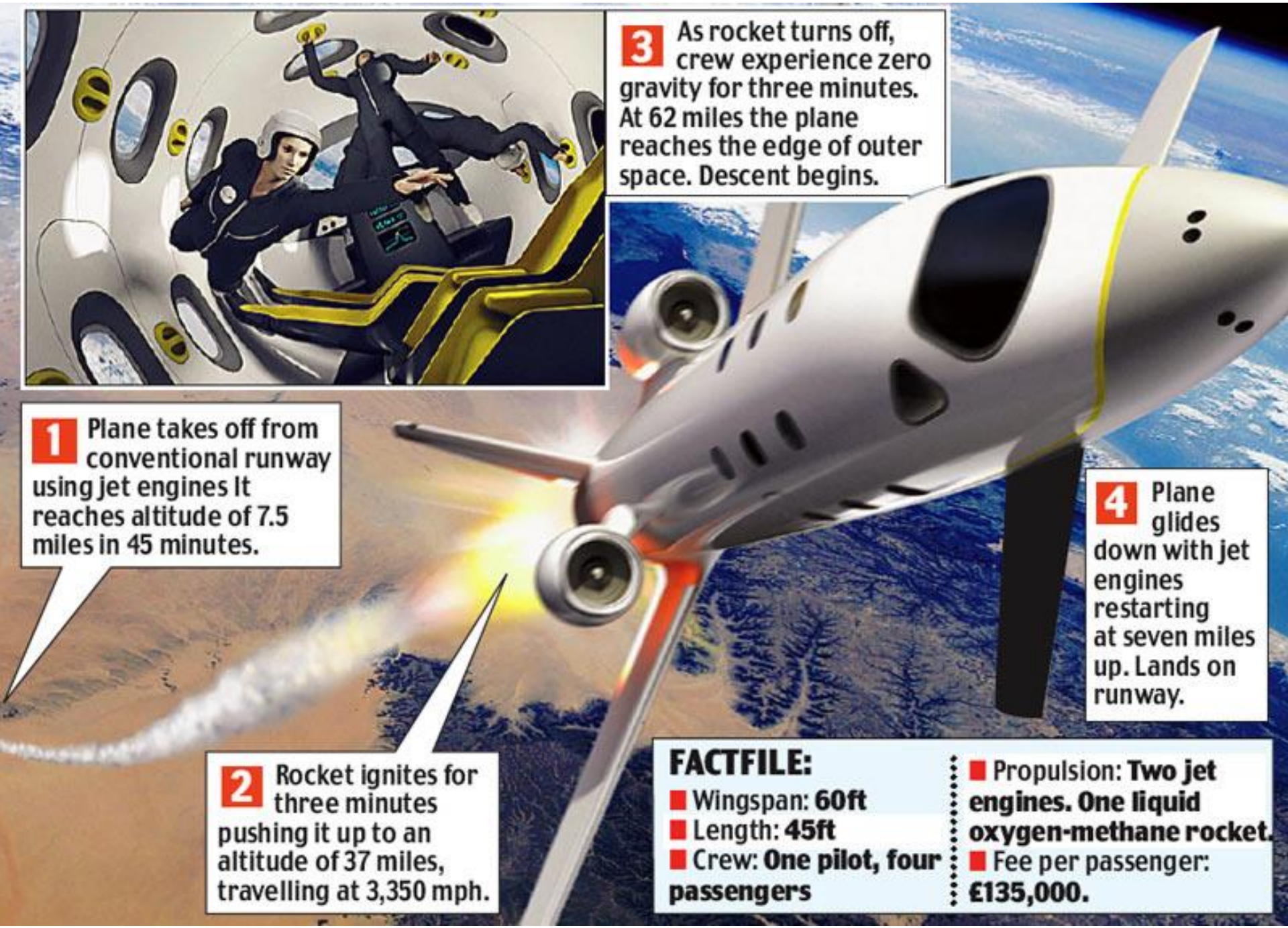
SpaceShipTwo will test this year and start paying flights in 2017 (?). Tickets are $250,000. They have $60 million in deposits and 15,000 expressions of interest. Note: there are 1000 billionaires in the world, and growing.

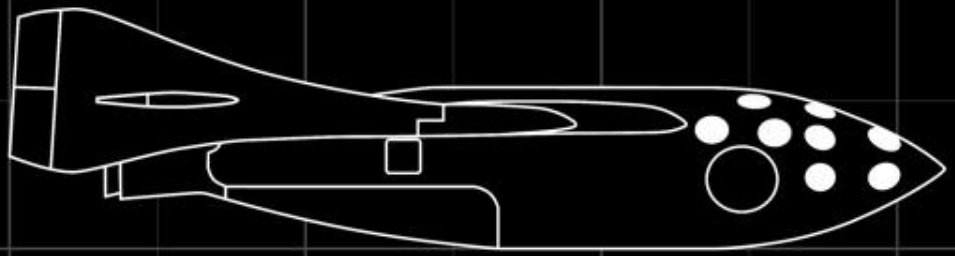
Lunar X Prize

Land a robot safely on the Moon, travel 500 meters, send back data and images, for a prize of$30 million.



Odyssey Moon
Astrobotic
Team Italia
Micro Space
So. Calif. Selene Group
FredNet
ARCA
LunaTrex
Quantum3
Chandah
Advaeros
JURBAN
STELLAR
Mystery Team


1 Plane takes off from conventional runway using jet engines It reaches altitude of 7.5 miles in 45 minutes.
2 Rocket ignites for three minutes pushing it up to an altitude of 37 miles, travelling at 3,350 mph.
3 As rocket turns off, crew experience zero gravity for three minutes. At 62 miles the plane reaches the edge of outer space. Descent begins.
4 Plane glides down with jet engines restarting at seven miles up. Lands on runway.
FACTFILE:
Wingspan: 60ft
Length: 45ft
Crew: One pilot, four passengers
Propulsion: Two jet engines. One liquid oxygen-methane rocket.
Fee per passenger: £135,000.



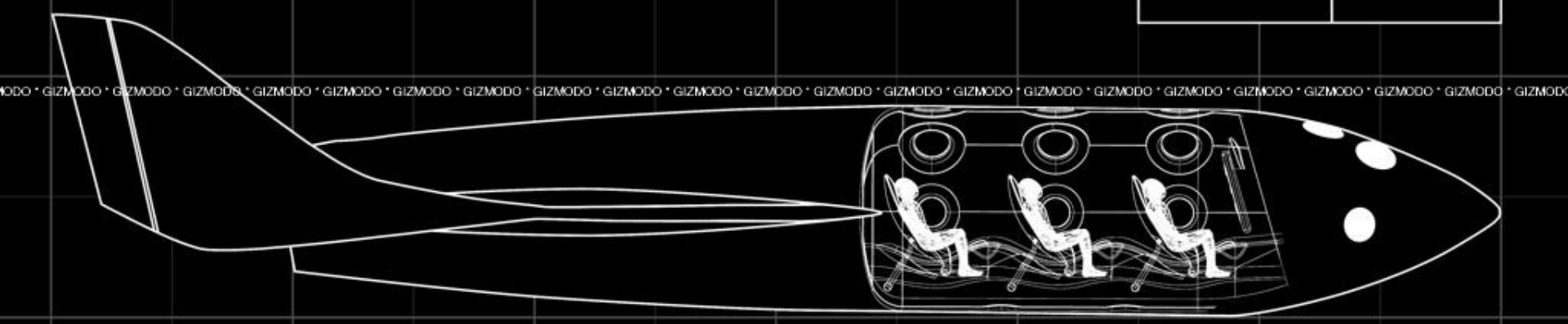
Virgin GALACTIC

SCALE COMPARISON CHART

SPACESHIPONE. SPACESHIPTWO

DATE: 28.09.06 | SCALE 1:68

↑ SpaceShipOne 28ft



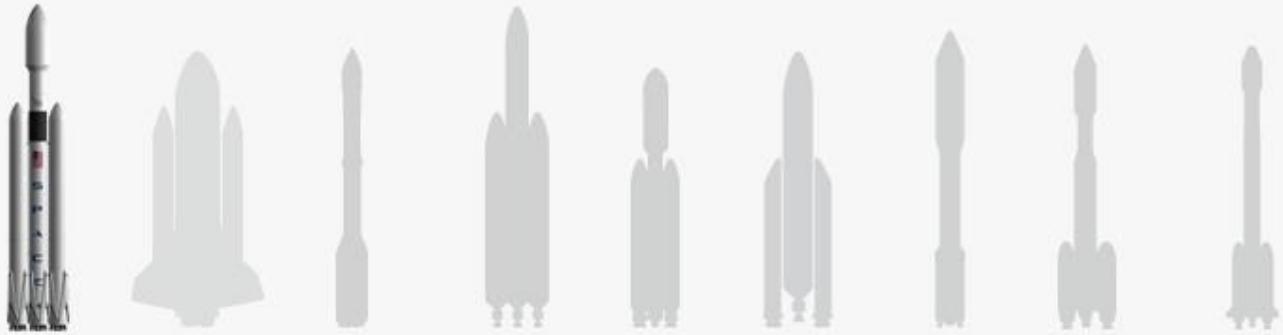
↑ SpaceShipTwo 60ft

FEET 10 20 30 40 50 60

Due to US Government regulations regarding technology transfer and commercial confidentiality, this is a conceptual representation of the exterior of SpaceShipTwo. SpaceShipTwo is currently under construction for Virgin Galactic at Scaled Composites in Mojave, California and is planned to be revealed for the first time in the second half of 2007. She will be named Virgin SpaceShip (VSS) Enterprise.

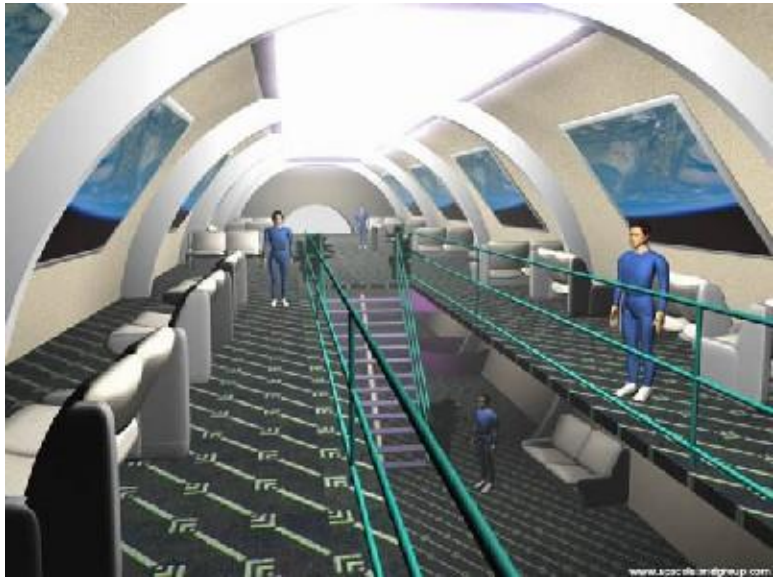

SPACEPORT AMERICA
Virgin
GALACTIC

Space X is redesigning their rockets from scratch. They have already resupplied the Space Station and plan a heavy lift capability into orbit (Falcon) and reusable rockets (Grasshopper).



LAUNCH VEHICLE	FALCON HEAVY	SPACE SHUTTLE	PROTON M	DELTA IV HEAVY	TITAN IV-B	ARIANE 5 ES	ATLAS V 551	JAPAN H2B	CHINA LM3B
PAYLOAD TO LOW EARTH ORBIT (LEO)	53,000 kg 116,850 lb	24,000 kg 53,790 lb	23,000 kg 50,710 lb	22,560 kg 49,740 lb	21,680 kg 47,800 lb	20,000 kg 44,090 lb	18,510 kg 40,810 lb	16,500 kg 36,380 lb	11,200 kg 24,690 lb

Economic Model



Trip in the next 40 years (once in a lifetime):

8% would pay 1 month salary.

13% would pay 3 months salary.

12% would pay 6 months salary.

49% would pay a year's salary.

Mean salary: $80k

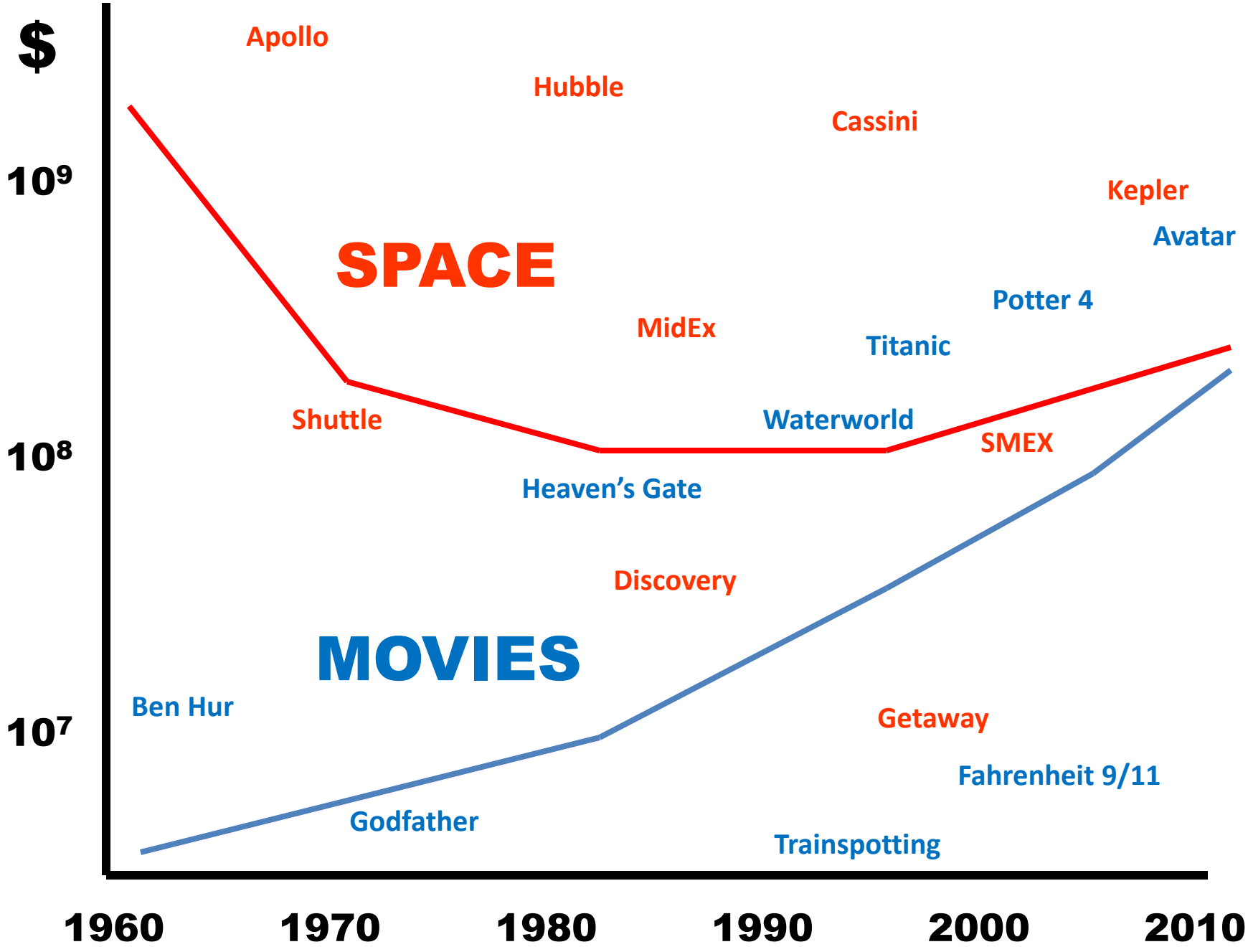
30 million college grads

Not in the market

Not in the market

If price 5x lower:
Yield = $20 billion

If price 2.5x lower:
Yield = $110 billion


$
10^9
10^8
10^7
Apollo
Hubble
Cassini
Kepler
Avatar
SPACE
Potter 4
MidEx
Titanic
Shuttle
Waterworld
SMEX
Heaven's Gate
Discovery
MOVIES
Ben Hur
Getaway
Fahrenheit 9/11
Godfather
Trainspotting
1960
1970
1980
1990
2000
2010

THE INTERNET

COMMERCIAL

RESEARCH

MILITARY

PIONEER

Google

DARPA

RAND CORPORATION

CERN

1960 1970 1980 1990 2000

SPACE TRAVEL

PIONEER

MILITARY

RESEARCH

COMMERCIAL

1920 1950 1980 2010 2040

Funny Oops

Funny Oops

Real Oops

Real Oops

Leonov Space Walk

Leonov Space Walk

Apollo 13

Apollo 13

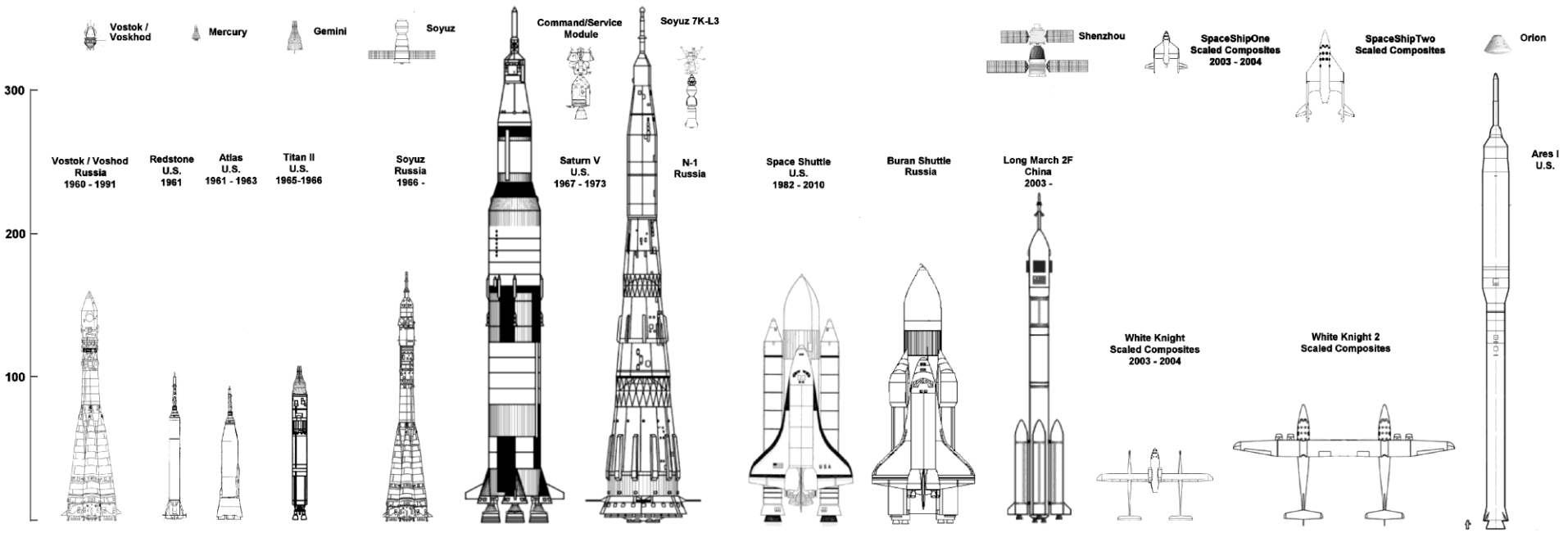
Worst Case Scenario

Worst Case Scenario

The Inside Scoop

The Inside Scoop

Future Technology



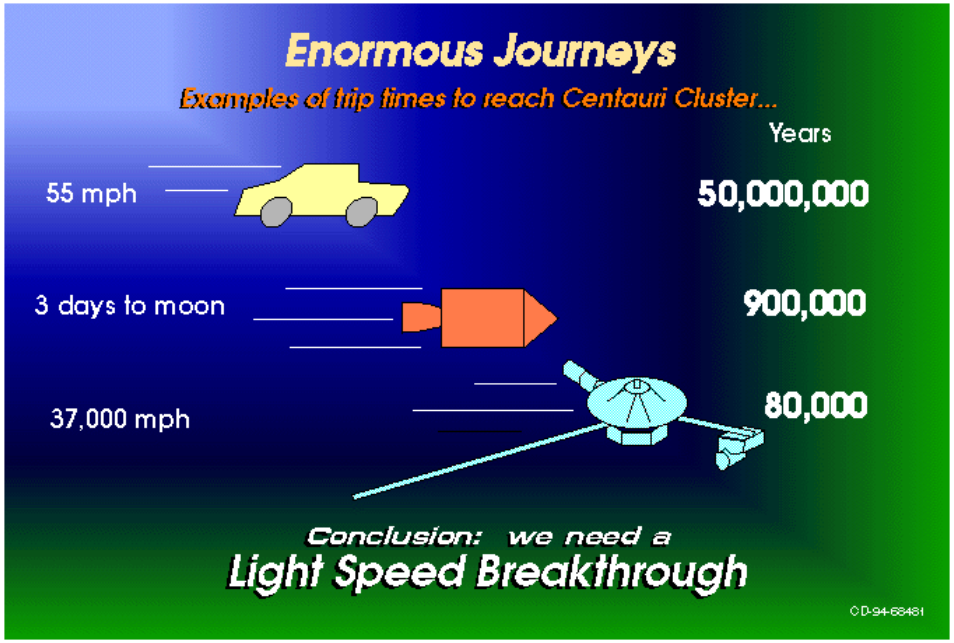
All rockets since Goddard have been based on inefficient chemical energy, using either liquid or solid fuel. Leaving the Earth is governed by the rocket equation, which for chemical energy mean 90% of the payload has to be fuel.

How far and how fast?

The most distant spacecraft is Voyager 1, launched in 1977 (with a 4yr mission), and now **14 billion km, or 9 billion miles** away, three times the distance of Pluto.

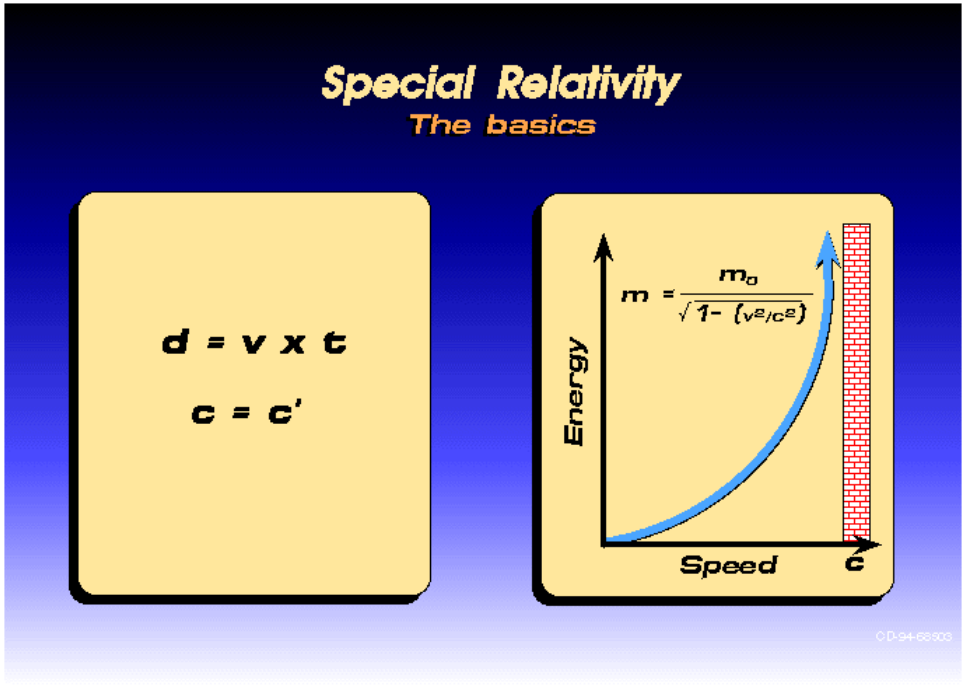
The fastest spacecraft was Helios 1, a solar probe launched in 1974, that reached a top speed of **250,000 km/h, or 160,000 mph**.

Current speeds are too slow...

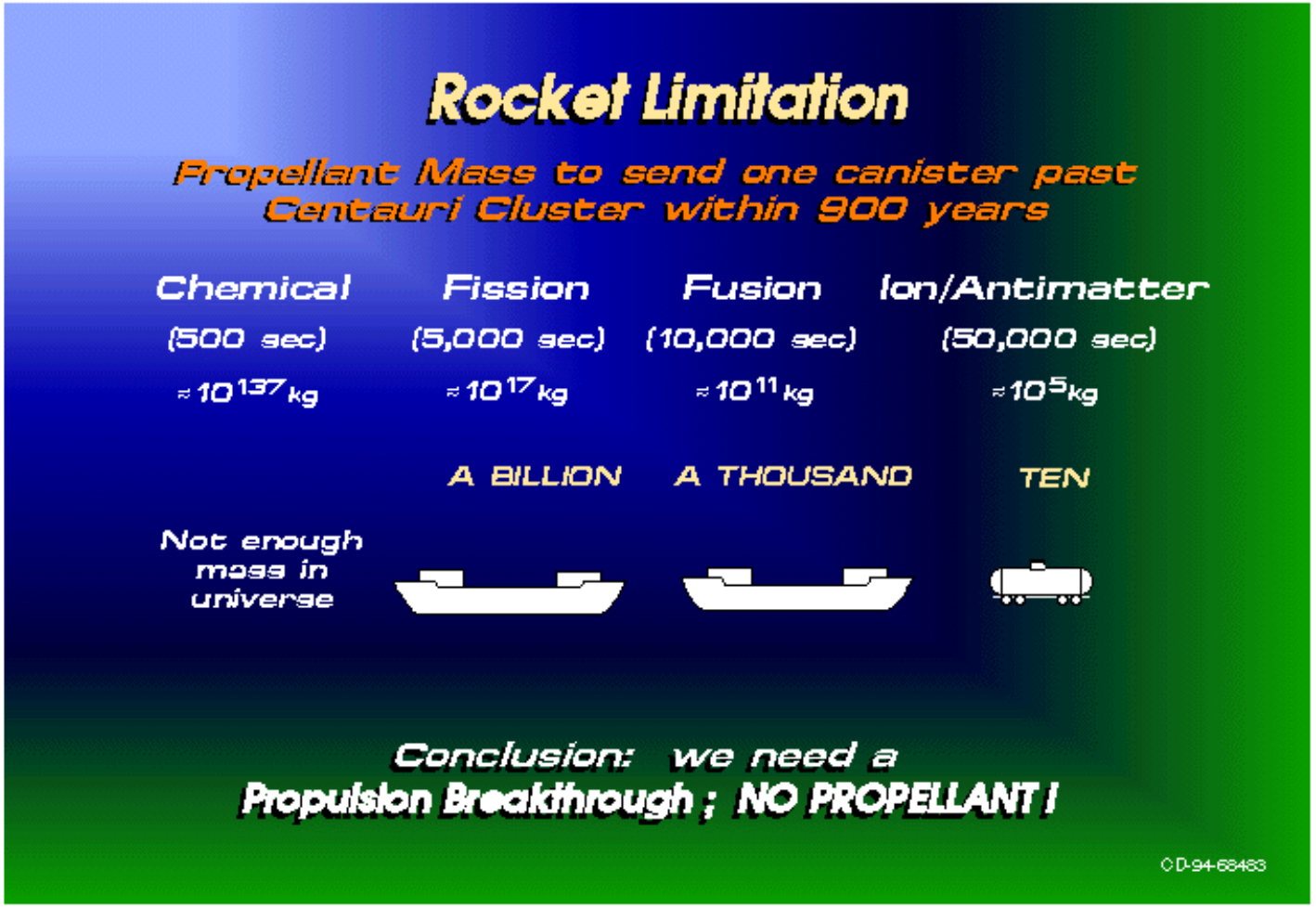


So the fastest spacecraft would take **10,000** years to reach the nearest stars since it can only travel at **0.2%** of the speed of light. This is far too slow for a realistic interstellar transport.

Fundamental physics imposes a limitation. As light speed is approached the energy from propulsion goes into increased mass, via $E = mc^2$, rather than increased speed. Energy costs are formidable above 10% of c.

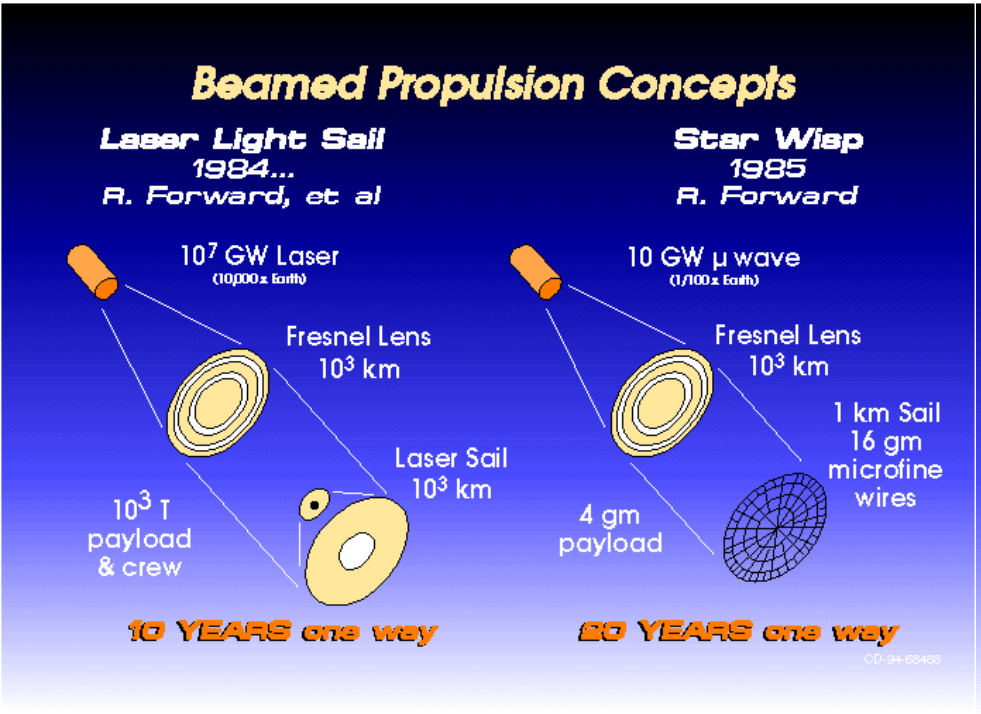


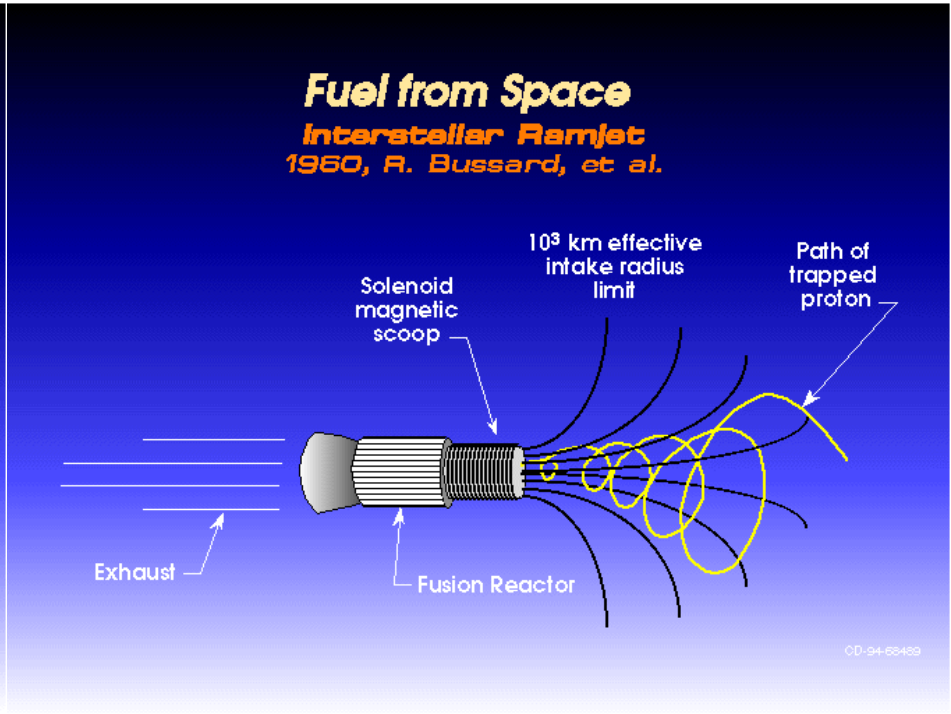
…and fuels are not good enough...



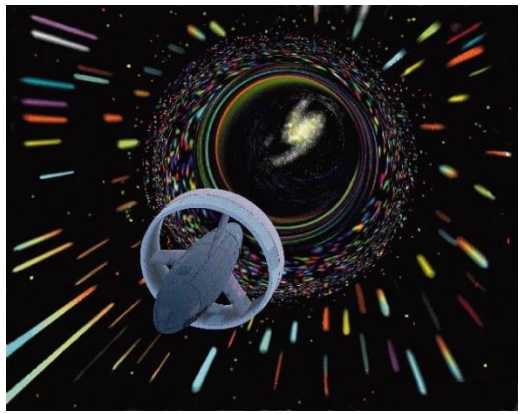
Chemical and even nuclear fuel is not the way to go, because too much fuel must be carried on board. So what's the answer?

Ideas for the Future





There are very plausible ideas to work on, but **warp drive and worm holes** may have to wait.



Imagining Worm Holes

***Contact* (1997)**

Imagining Worm Holes

***Contact* (1997)**

Interstellar Travel

1. How far do we have to go?
   To reach another star: α Centauri, 4.2 light years away.
   To reach a known planetary system: ε Eridani, 10 light years away
   To reach a planet like the Earth: who knows?

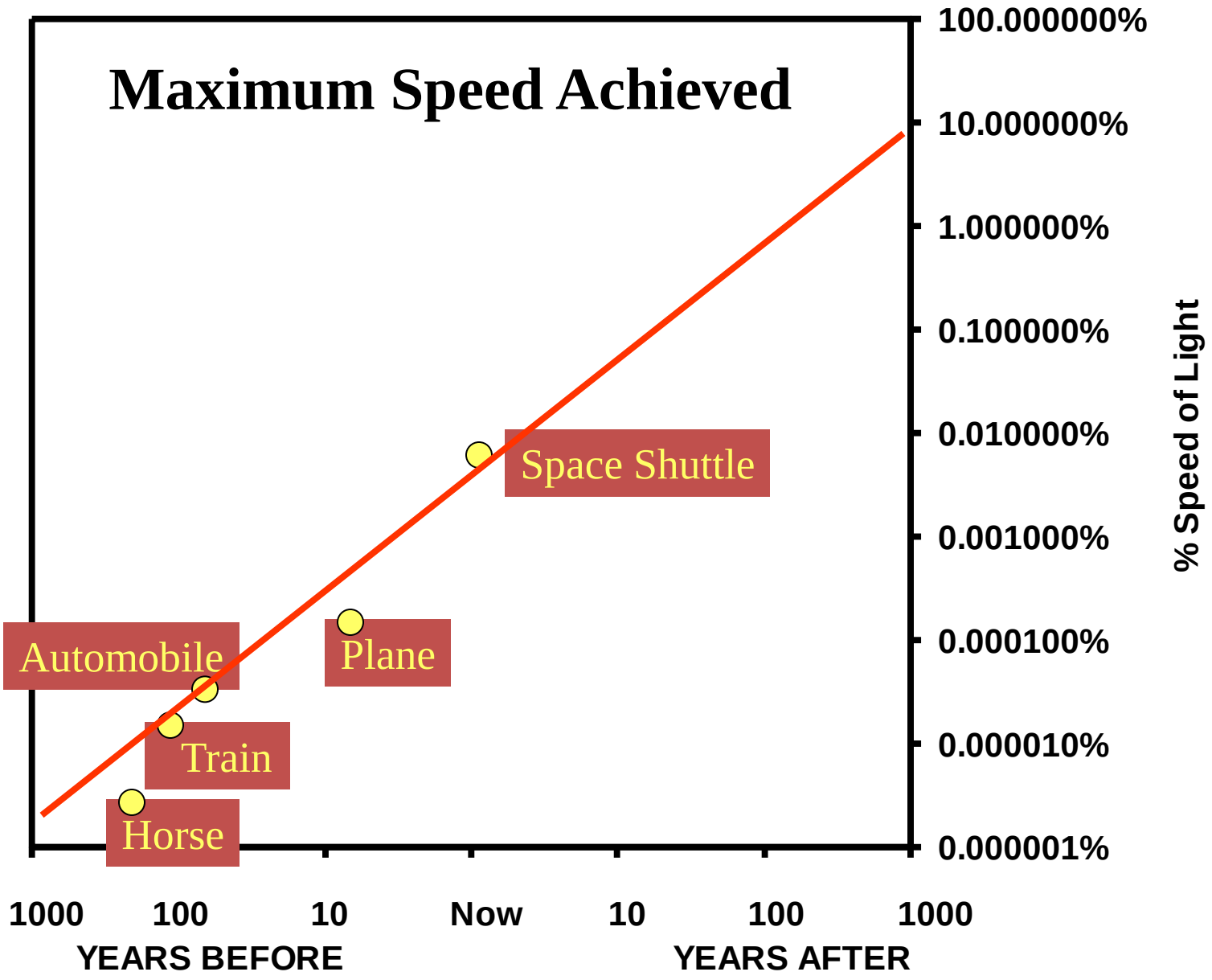
2. How long do we want to wait?
   Adult life: 50 years
   Multi-generation travel: 30 generations = 1000 years?
   (Linguistic and cultural stability becomes an issue…)

3. How long will it take?

At 30 km/s (solar sail, ramjet):	4.2 light years in 42,000 years
At 3000 km/s (nuclear pulse):	4.2 light years in 420 years
Near the speed of light (anti-matter):	4.2 light years in 4.2 years

Galactic Centre in 24,000 years; nearby galaxies in 2-10 million years

Note: Teleportation — remote reconstruction of matter at light speed — is not ruled out by the laws of physics. Quantum collapse of the wave function does not prevent it.


Maximum Speed Achieved
100.000000%
10.000000%
1.000000%
0.100000%
0.010000%
0.001000%
0.000100%
0.000010%
0.000001%
% Speed of Light
Space Shuttle
Plane
Automobile
Train
Horse
1000
100
10
Now
10
100
1000
YEARS BEFORE
YEARS AFTER

Why go Fast?

Slow transport is possible, and the only option to carry any significant payload.

Multigenerational craft or "space arks": carry an entire ecosystem and civilization.

Stasis craft: carry crew in hibernation.

Clone craft: carry just the genetic information to create a colony at the destination (and good enough androids to raise them!)

Robotic craft: No crew, but robots that can make more robots and do the dirty work of terraforming distant planets on arrival.

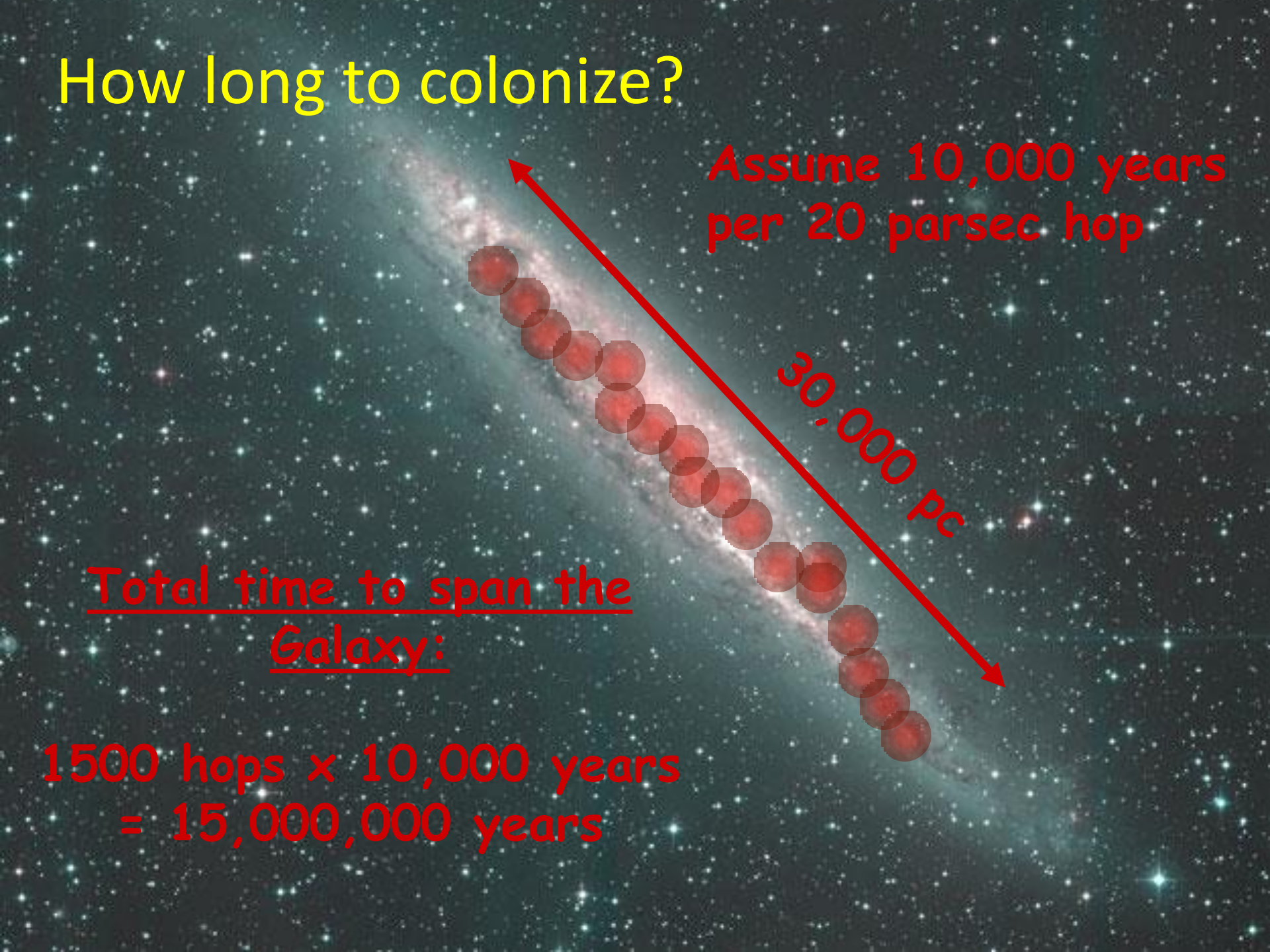
Galactic Colonization

Depending on assumptions, ~1-10% of solar stars have terrestrial planets
Distance between suitable planets: about 20 parsecs

Maximum speed of conceivable multigenerational craft: 0.001 to 0.01*c*
Travel times are in the range 1,000 to 10,000 years

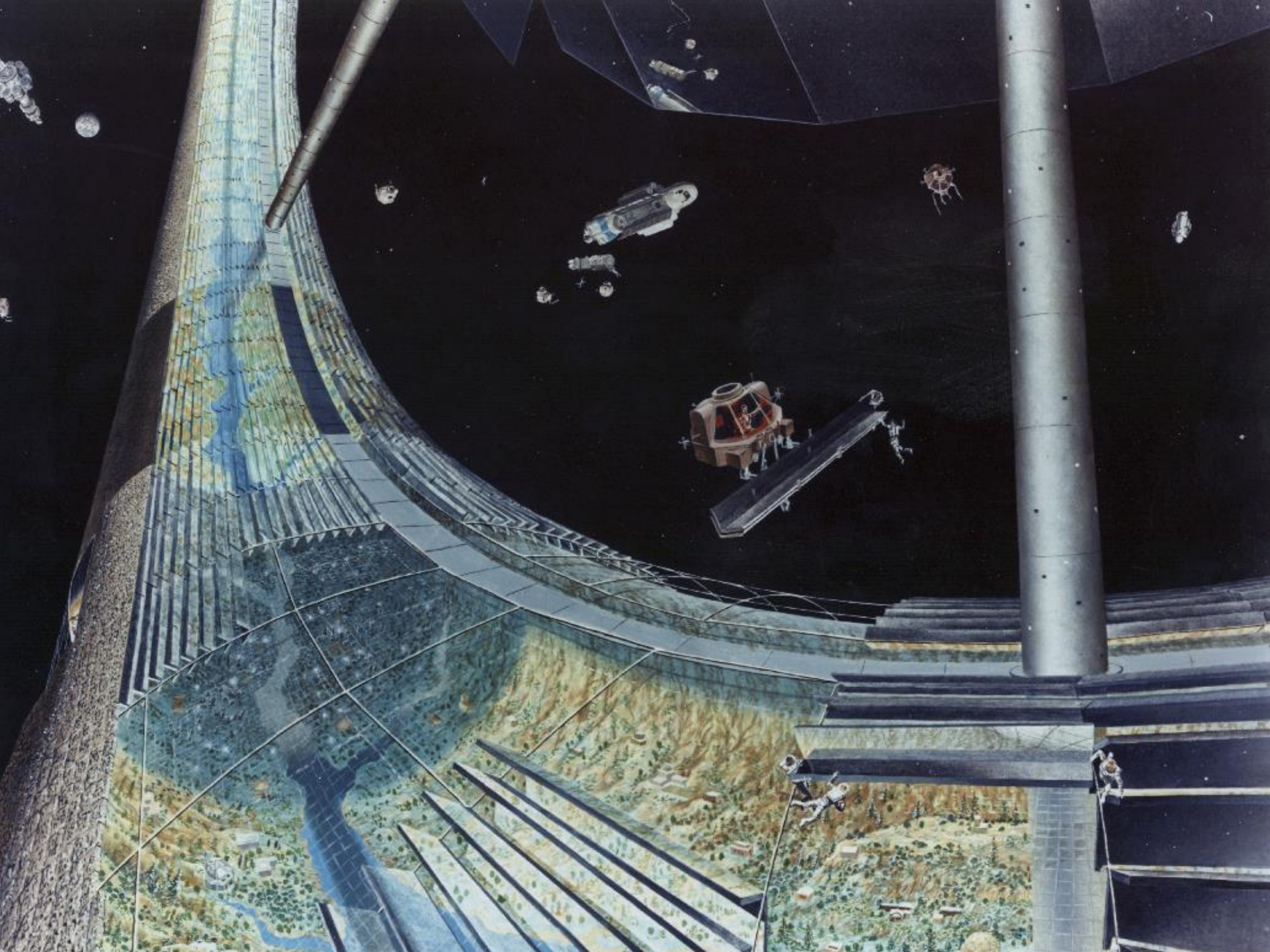
If new craft are built and sent out soon after colonization, we'd span the Galaxy in ~10 million years. Could any civilization do this? Will we?

How long to colonize?



Total time to span the Galaxy:

1500 hops x 10,000 years
= 15,000,000 years



Cosmos Remixed

Cosmos Remixed