

H2MM

Let's Talk \$\$

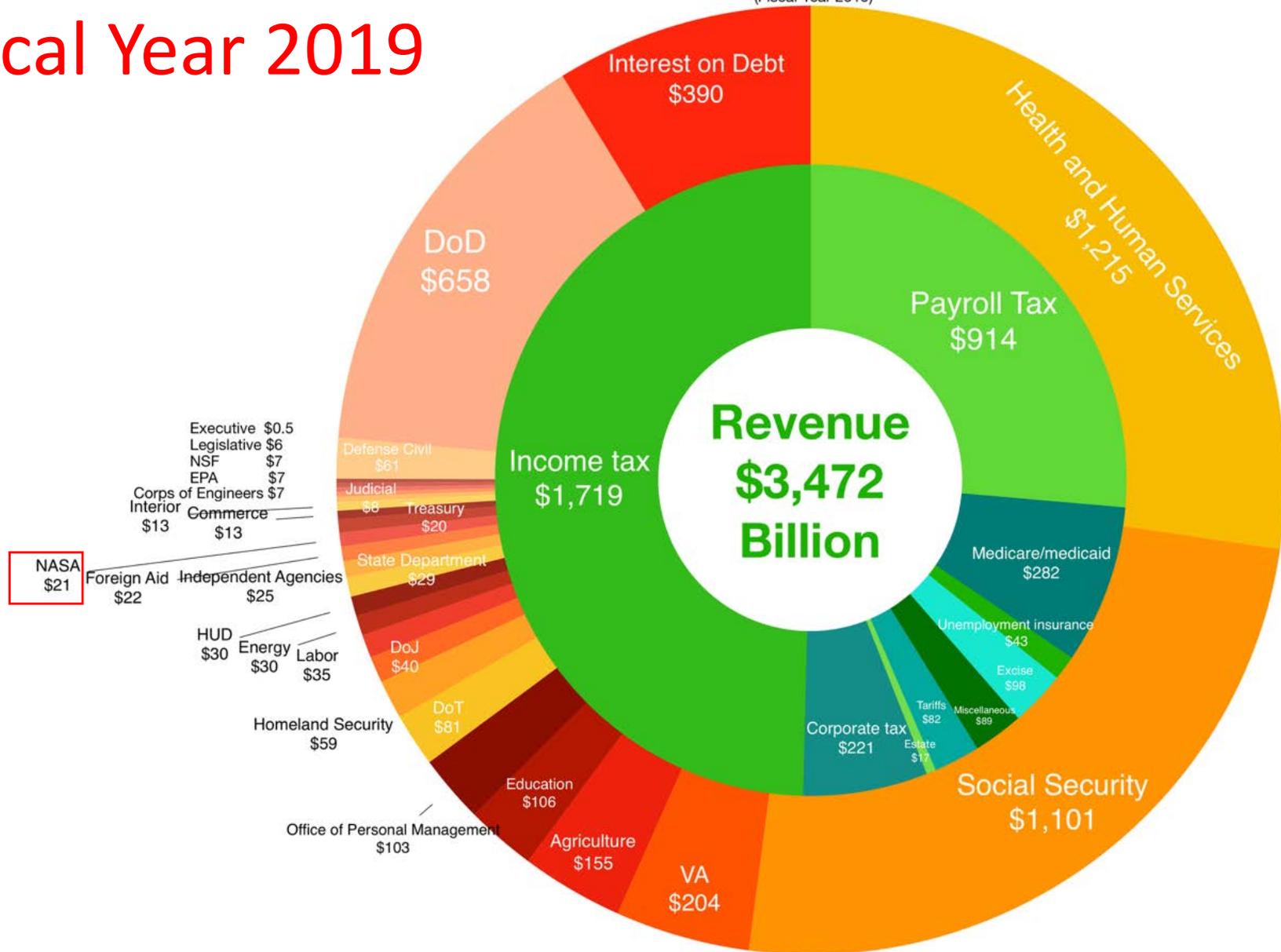
Fran Bagenal

- Start with the big picture – Fed Govt & NASA
- Mission costs
- Priorities

Federal Spending and Revenue

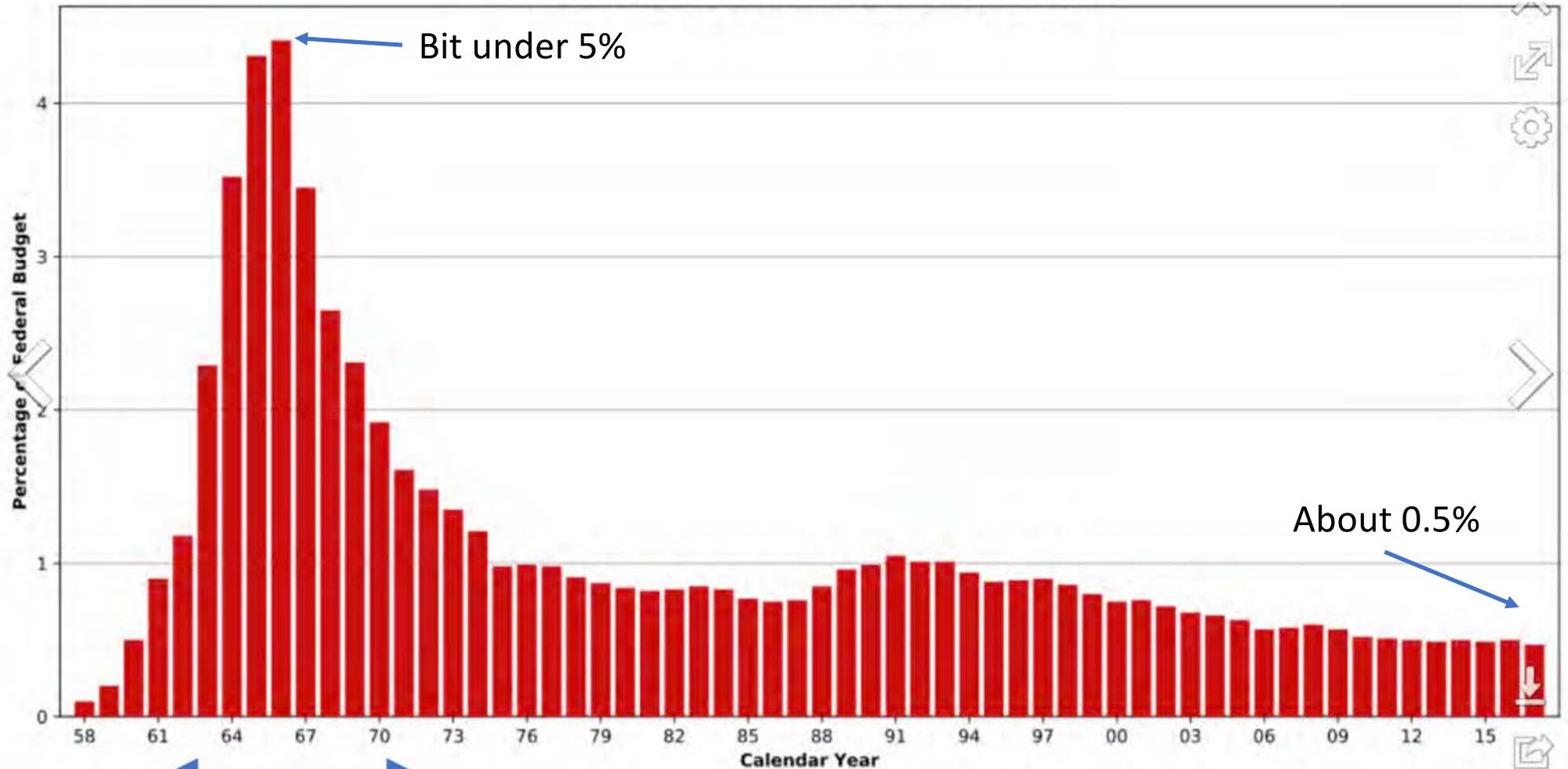
(Fiscal Year 2019)

Fiscal Year 2019



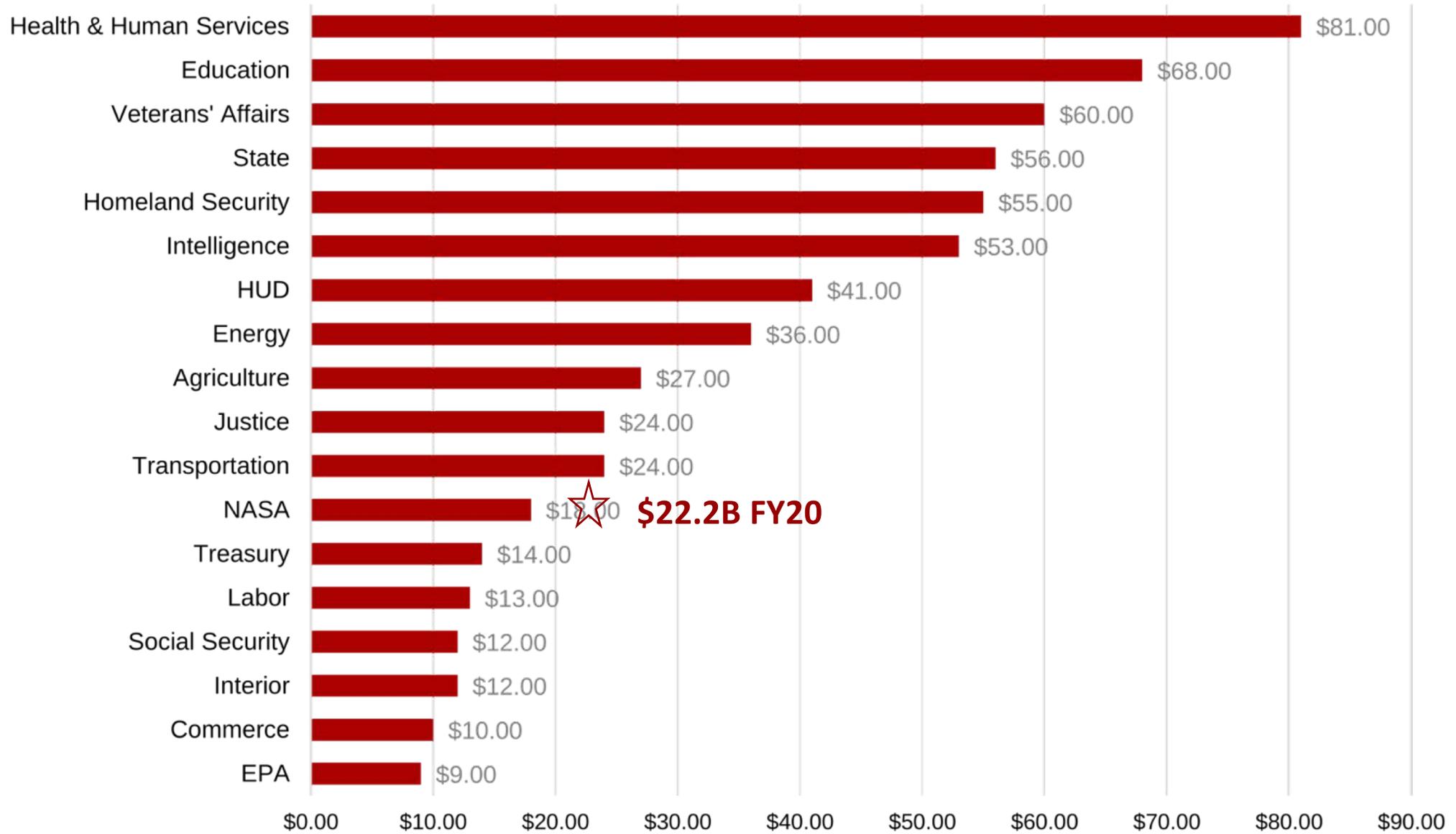
Spending
\$4,472
Billion

NASA budget as Percentage of Federal Budget



Apollo Program 1961-1972

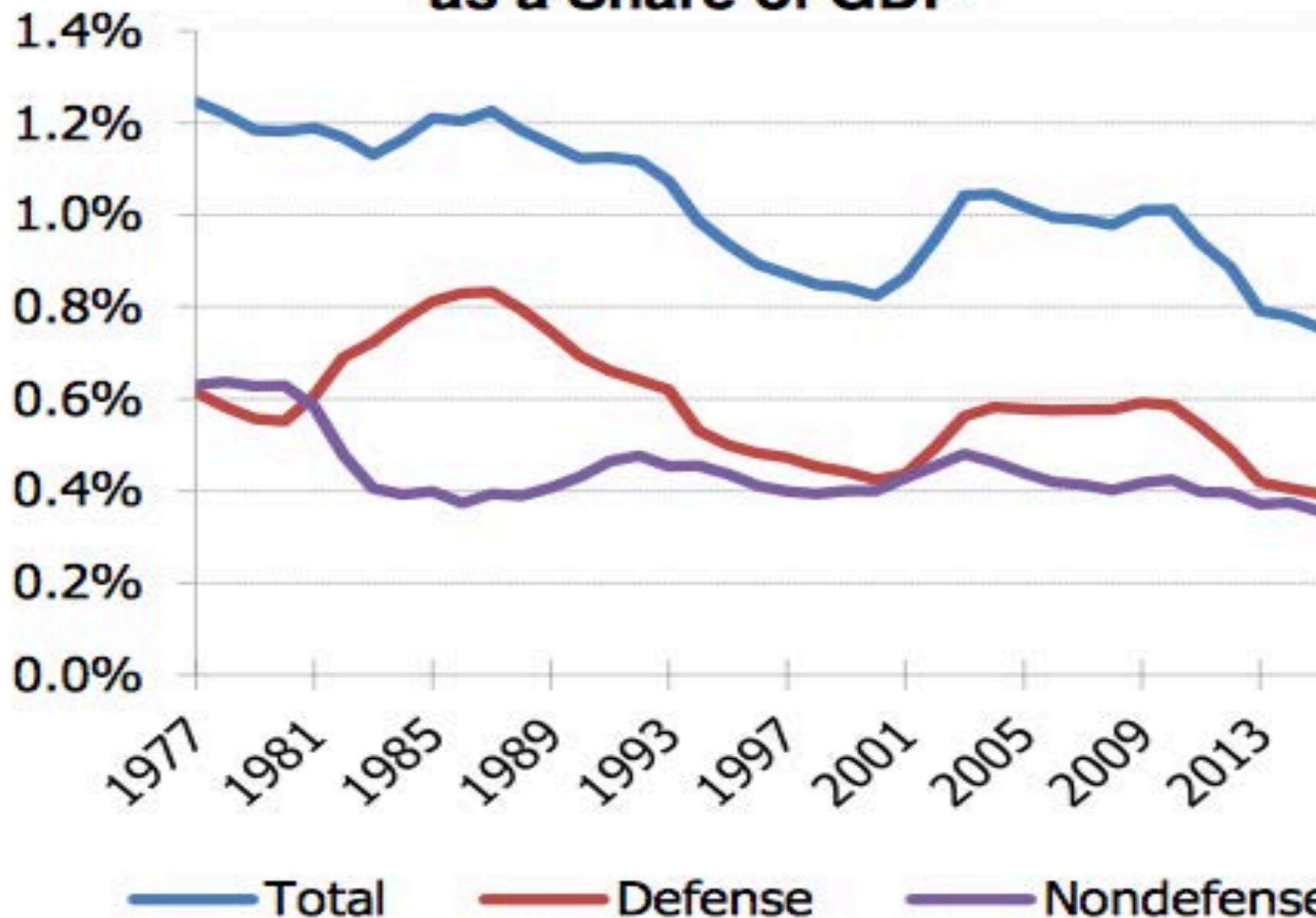
Discretionary Spending by Department & Agency - FY 2013



Source: Office of Management & Budget

Note: Several Departments have large mandatory appropriations as well

Figure 6: Federal R&D as a Share of GDP



Based on AAAS analysis of historical R&D and GDP data.
© 2014 AAAS

Non-Defense Research Budgets

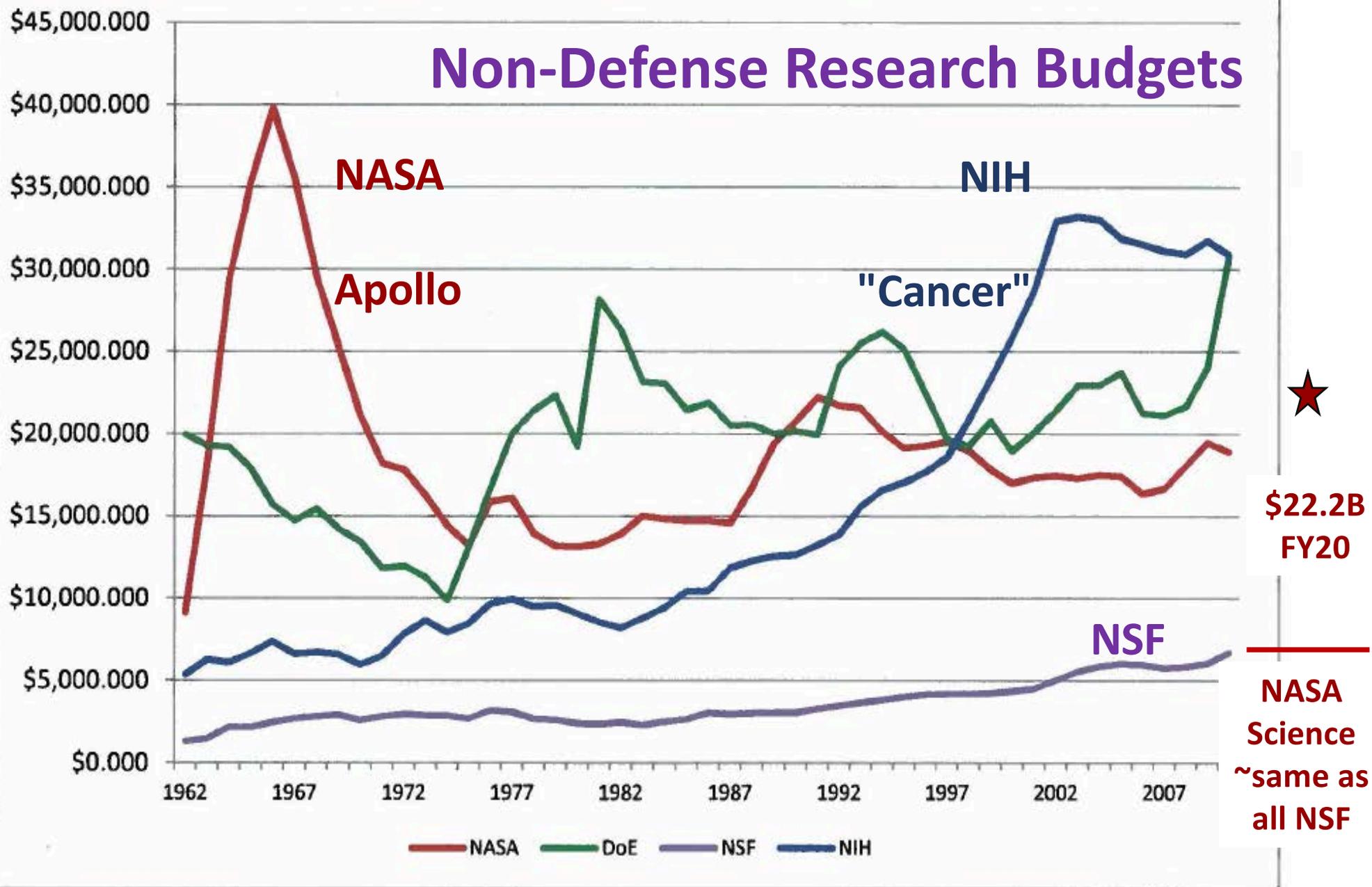
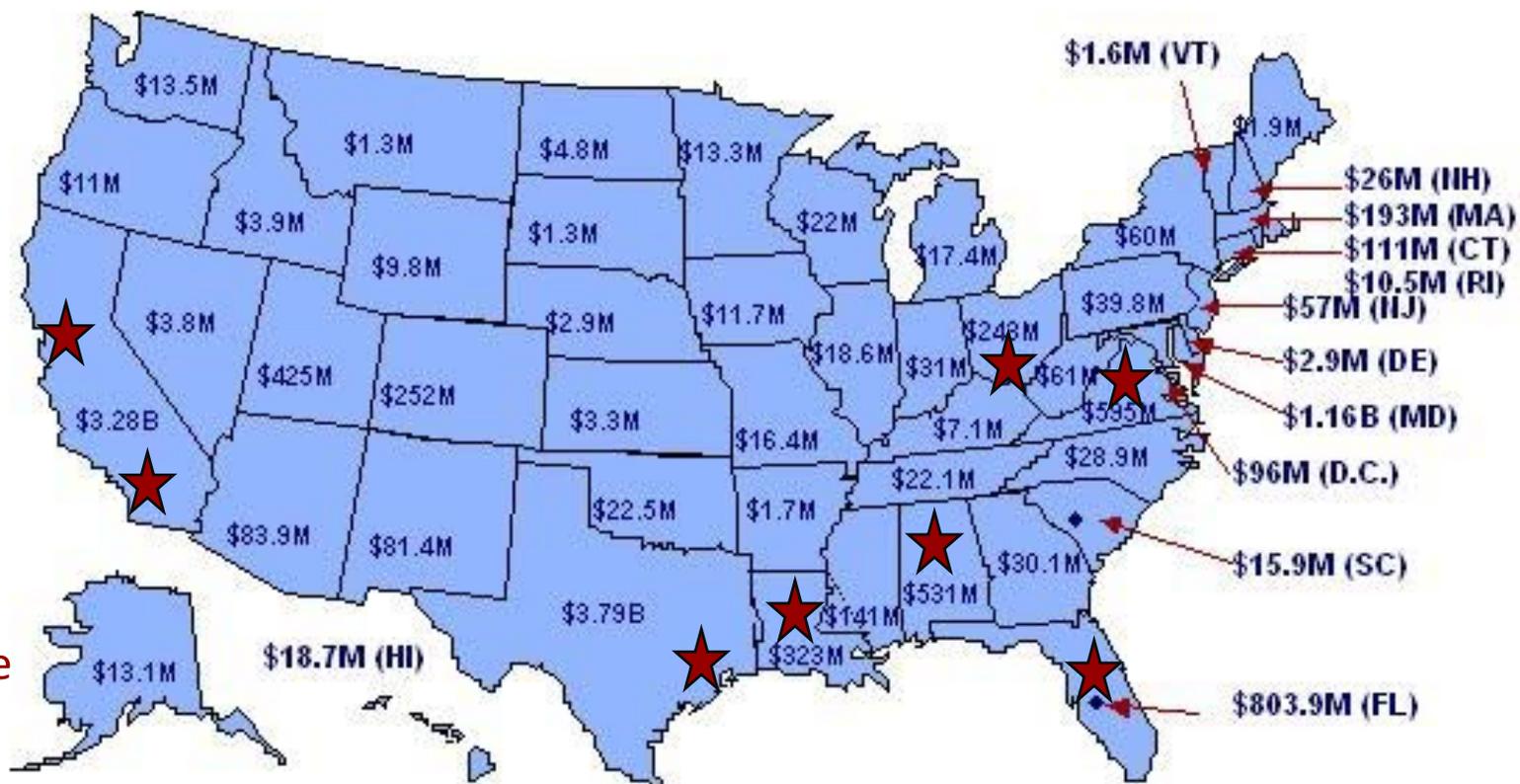


Table V. NASA, NSF, NIH, and Department of Energy Outlays, 1962-2010
 (\$M, adjusted to 2010)

NASA Dollars Boost the Economies of Every State in the U. S.

★ Main
NASA
Centers

Spend NASA funds on maintaining 10 centers?
Or slim down NASA bureaucracy to fund innovative non-Govt efforts?

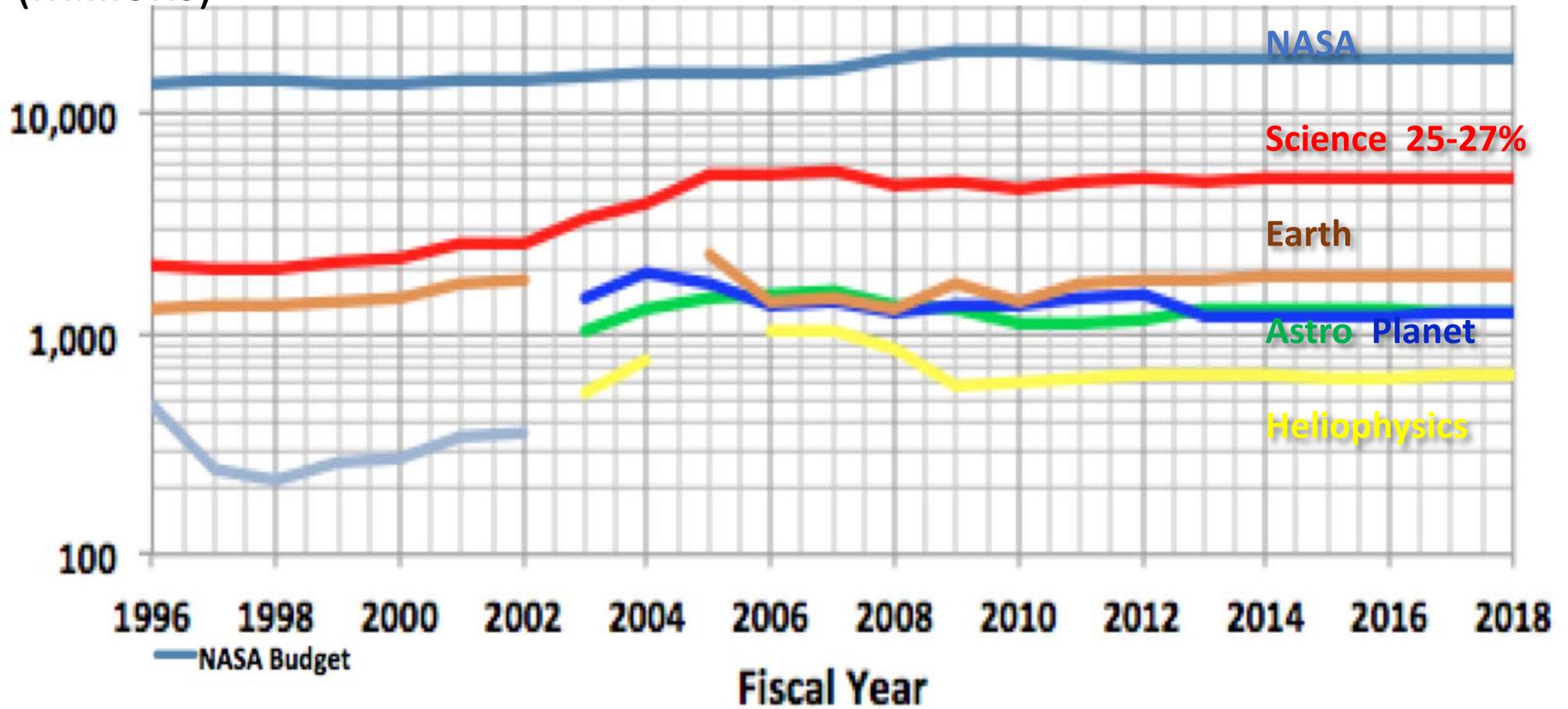


■ All 50 states and the District of Columbia participated in NASA procurements in FY '03

■ Grants and awards went to various educational institutions and non-profit organizations in 50 states and the District of Columbia

Real Year \$
(millions)

NASA Science Budget 1996-2018



— Space Science Total

— Heliophysics Budget

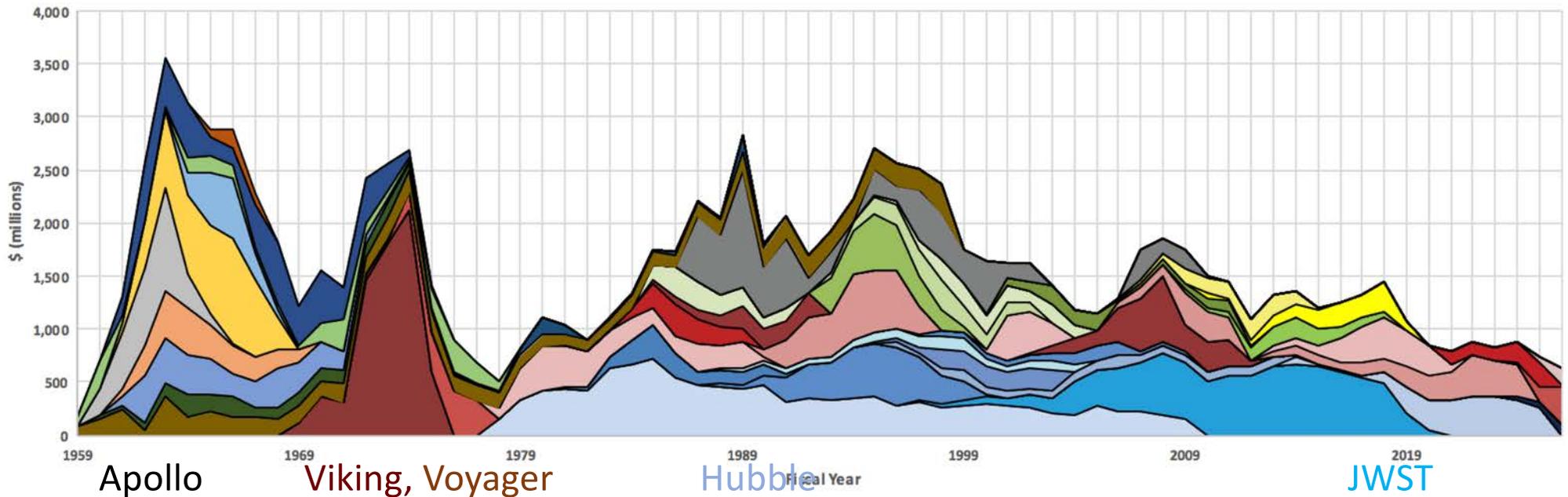
— Astrophysics Budget, including James Webb Space Telescope and Astronomical Search for Origins in FY2003 and FY2004

— Planetary Science Budget, including Mars Exploration (where separate in FY2003 and FY2004)

— Earth Science Budget

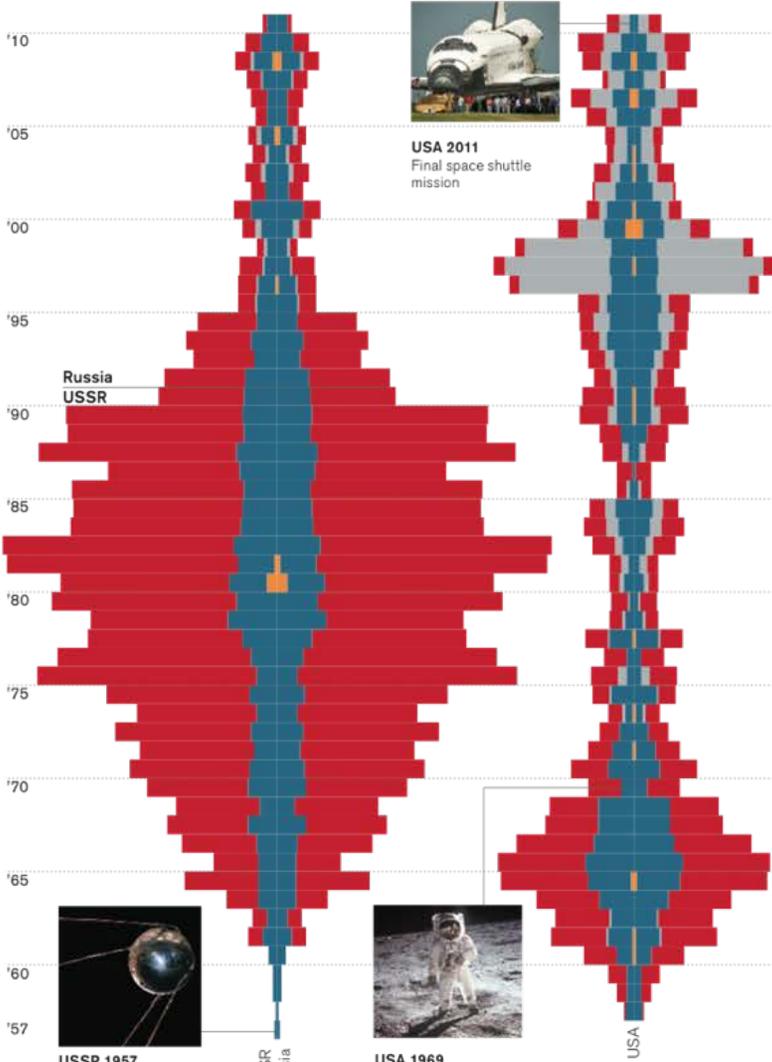
— Life Science Budget

NASA Annual expenditures for science missions in FY 2015 millions of dollars for 57 years (1969 - 2026)

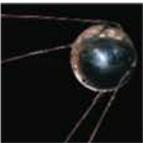


- Viking
- Chandra
- Wide Field Infrared Survey Telescope (WFIRST)
- Gravity Probe - B (GP-B)
- Cassini
- Upper Atmosphere Research Satellite (UARS)
- Terra
- Astro 2030
- Juno
- Solar Probe Plus (SPP)
- New Frontiers 4 (NF 2024)
- Explorer Class
- Orbiting Astronomical Observatories
- Surveyor
- Mariner
- Hubble (w/servicing , no ops)
- Compton Gamma-Ray Observatory (CGRO)
- SOFIA
- Space Interferometry Mission (SIM)
- Magellan (MGN)
- Mars Science Laboratory (MSL)
- Aqua
- Europa
- ICESat 2
- Magnetospheric Multiscale (MMS)
- Shuttle Launches
- Ulysses
- Orbiting Geophysical Observatories
- Lunar Orbiter
- Original Voyager
- James Webb Space Telescope (JWST)
- Voyager (VGR)
- Spitzer
- Galileo
- Mars Orbiter (MO)
- Mars Exploration Rovers (MER)
- Aura
- Mars 2020
- SUOMI National Polar-Orbiting Partnership (SNPP)
- Mars 2030
- New Frontier 5 (NF 2029)
- Orbiting Solar Observatories
- Ranger
- Pioneer / Helios

SPACE LAUNCHES (payloads by country and purpose, annually)



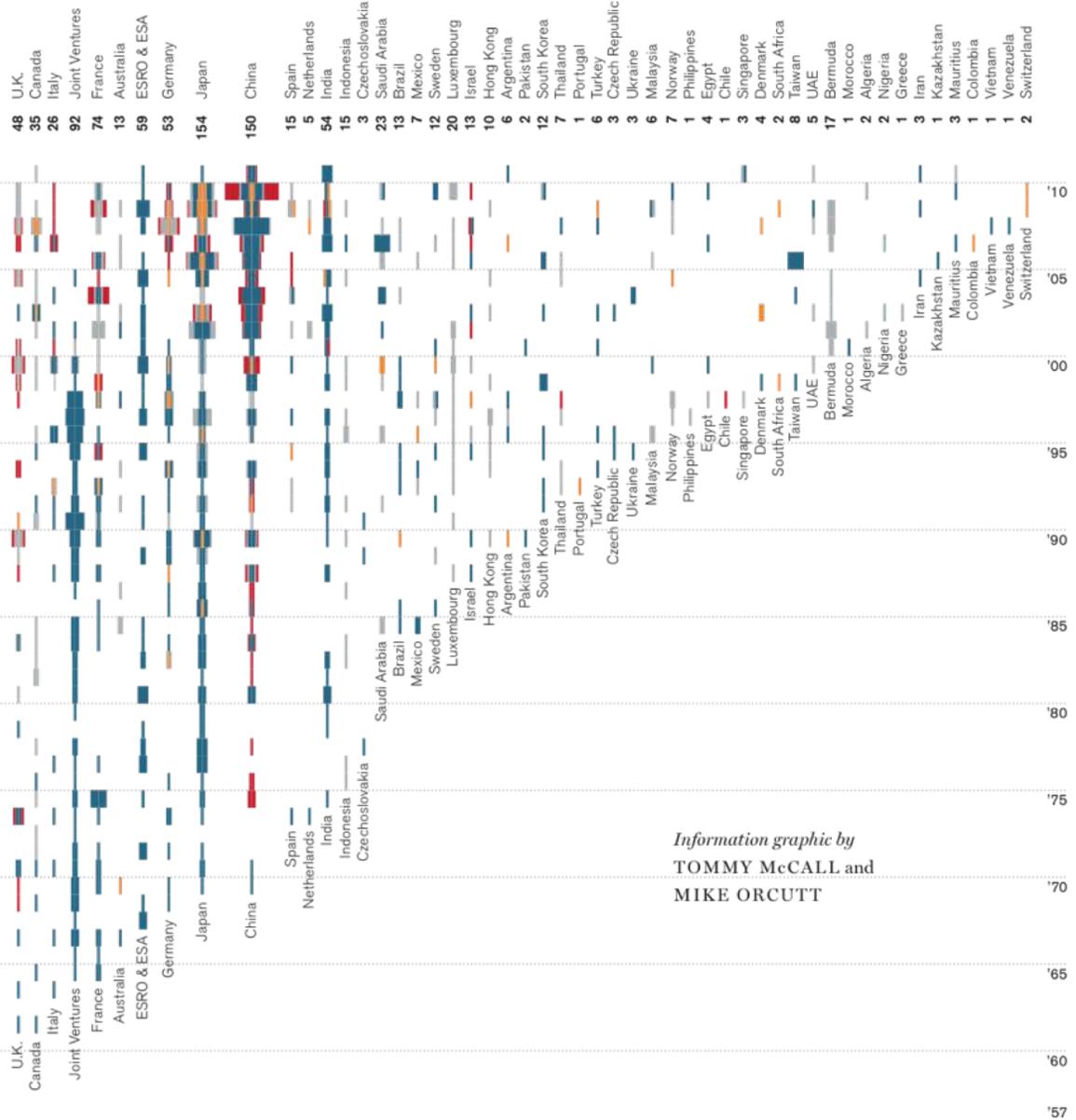
USA 2011
Final space shuttle mission



USSR 1957
Sputnik 1 placed into orbit



USA 1969
Apollo 11 moon landing



Notes: "Joint Ventures" refers to the multinational satellite consortia INTELSAT, INMARSAT, EUTELSAT, and EUMETSAT. The European Space Research Organization (ESRO) was a forerunner to the European Space Agency (ESA), which was formed in 1975.

Information graphic by
TOMMY McCALL and
MIKE ORCUTT

Peak~100/yr

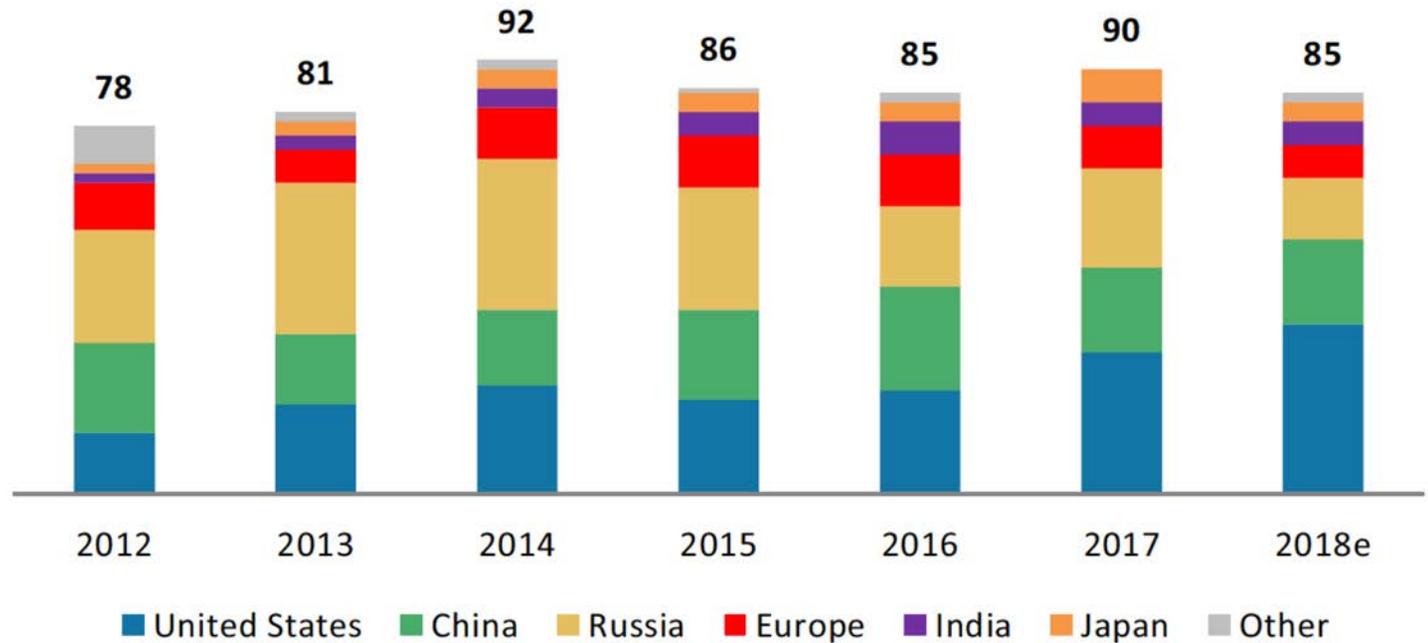
Peak~50/yr

NASA

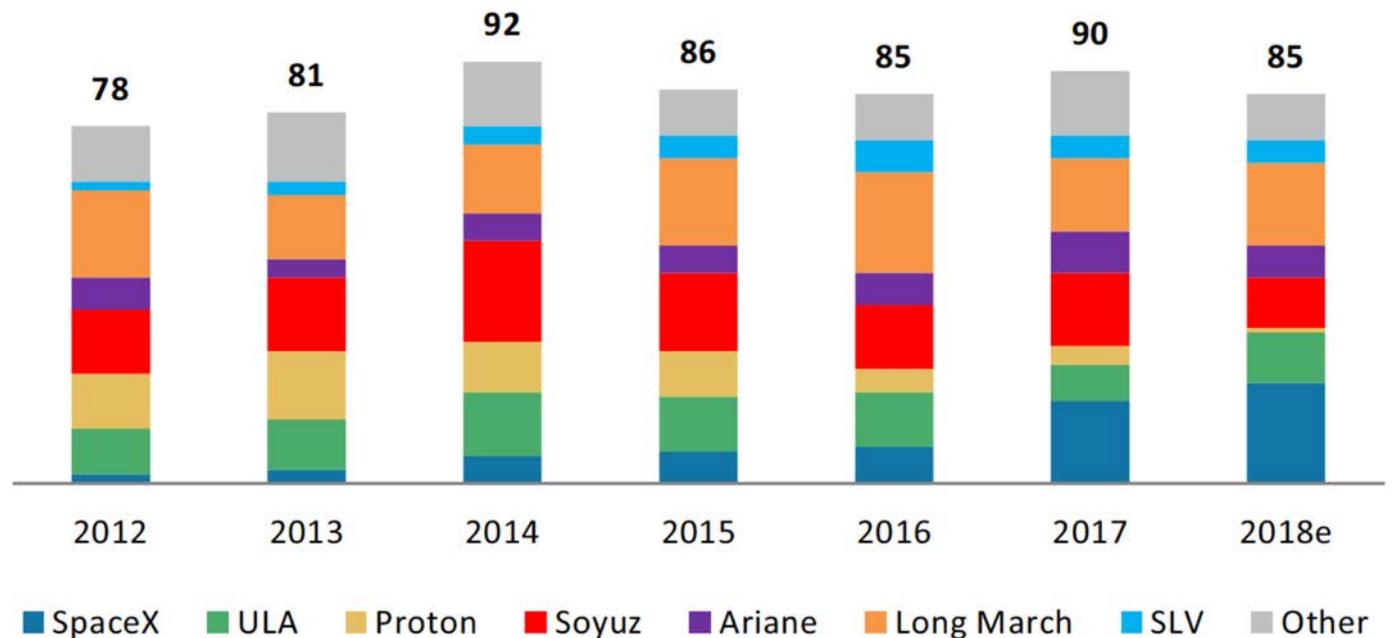
Launch Rates

Current Trends

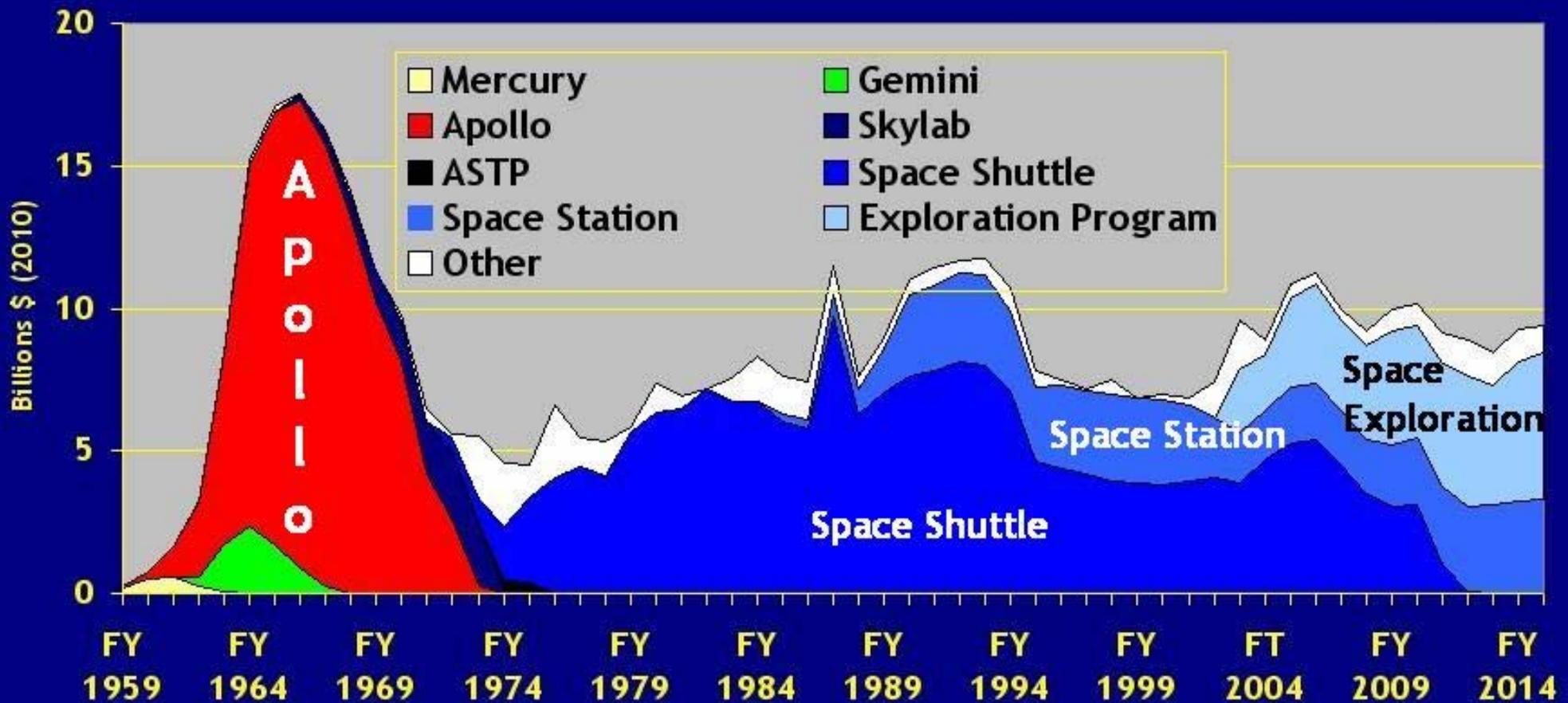
Satellite Launch Events (By Country)



Satellite Launch Events (By Rocket)



U.S. Piloted Programs Funding, 1959-2015 (2010\$)



© Claude Lafleur, Spacecraft Encyclopedia, 2010

The US has spent \$486 billion over 57 years on human spaceflight, an average of \$8.3 billion a year

– is this enough to get back to Moon? To Mars?

Pathways to Exploration: Rationales and Approaches for a U.S. Program of Human Space Exploration

– National Academy of Sciences - 2014

BUDGET DRIVEN ENHANCED EXPLORATION ANNUAL COST (THEN-YEAR \$)

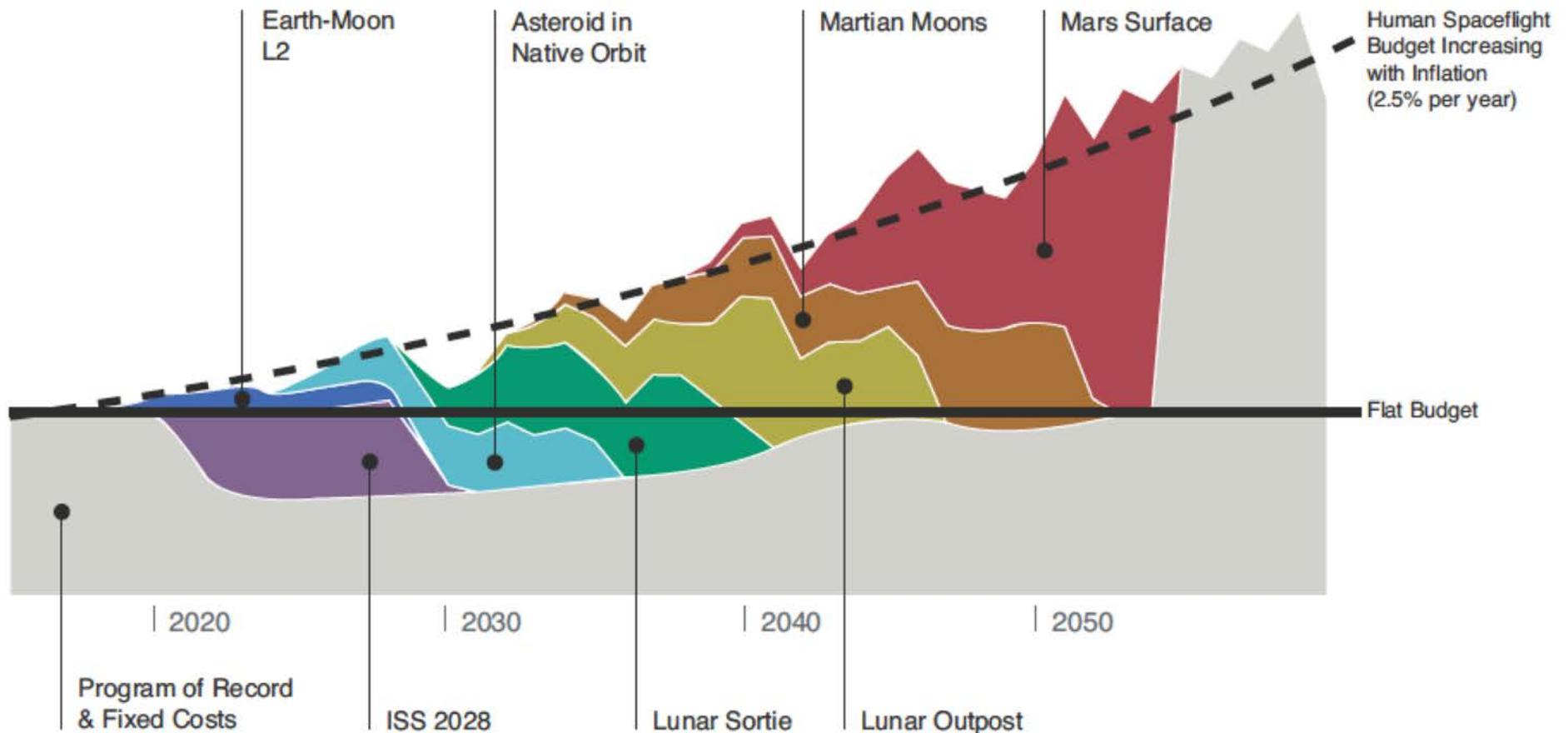


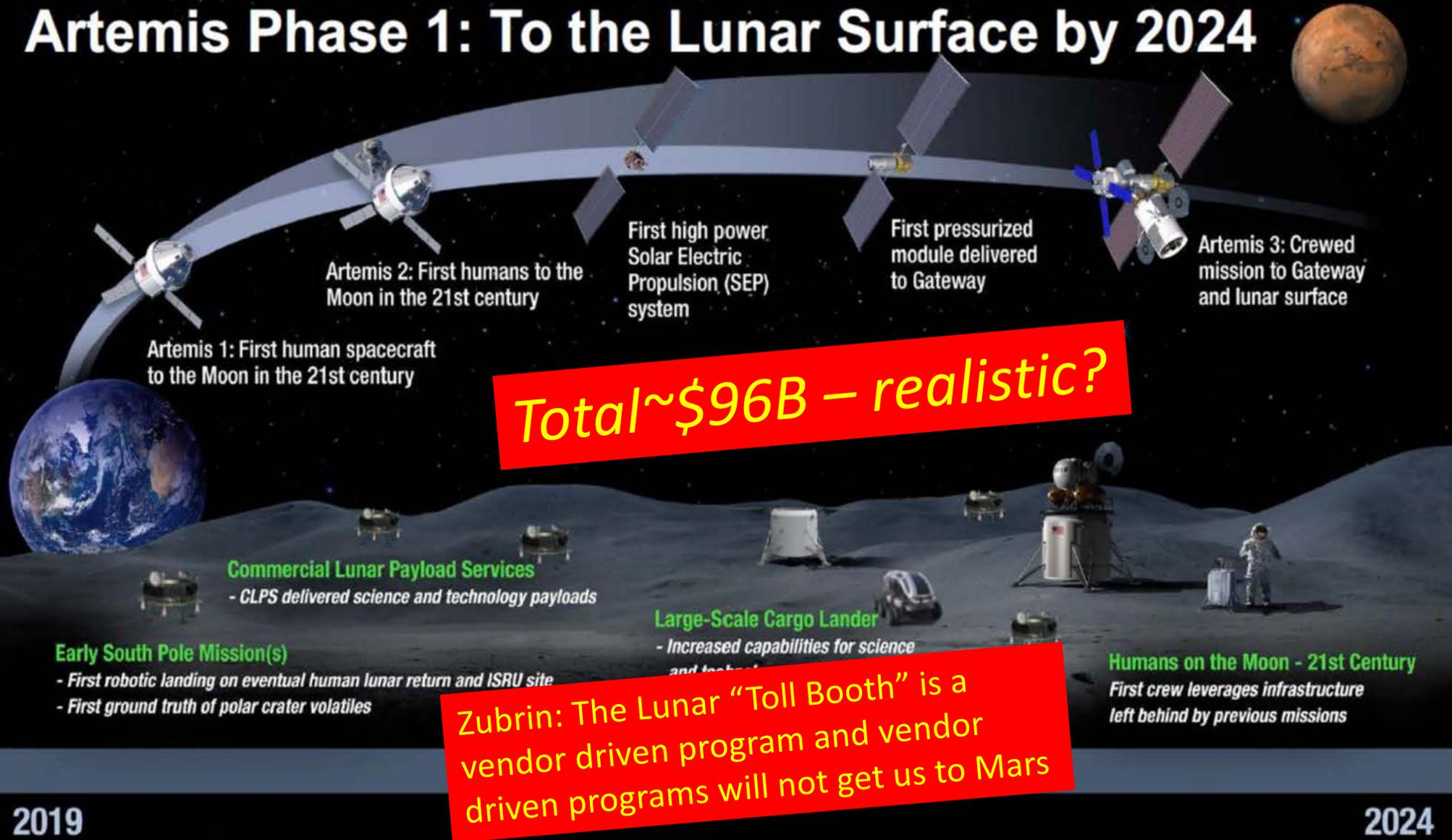
FIGURE 1.11 A budget-driven pathway toward Mars.

NASA's Human Mission to the Moon:

Jack Burns

Project Artemis **\$30B**

Artemis Phase 1: To the Lunar Surface by 2024



Zubrin: The Lunar "Toll Booth" is a vendor driven program and vendor driven programs will not get us to Mars

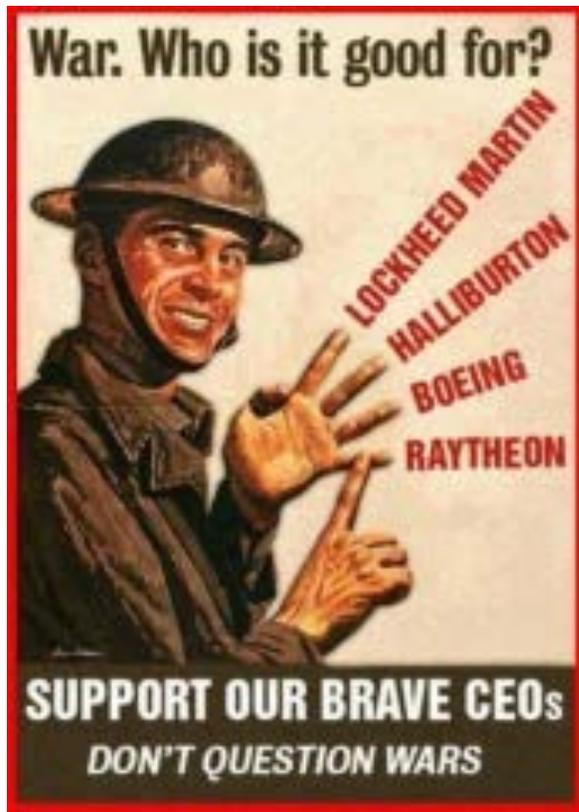
The Military Industrial Complex

"In the councils of government, we must guard against the acquisition of unwarranted influence, whether sought or unsought, by the military-industrial complex. The potential for the disastrous rise of misplaced power exists and will persist. We must never let the weight of this combination endanger our liberties or democratic processes. We should take nothing for granted. Only an alert and knowledgeable citizenry can compel the proper meshing of the huge industrial and military machinery of defense with our peaceful methods and goals, so that security and liberty may prosper together."

(Republican) President Eisenhower's
departing speech, Jan 17 1961



Military Industrial Complex



Millions of citizens are deeply disturbed that the military-industrial complex too often shapes national policy, but they do not want to be considered unpatriotic.

(Martin Luther King, Jr.)

President Johnson (Democrat)

LBJ's Space Race: what we didn't know then

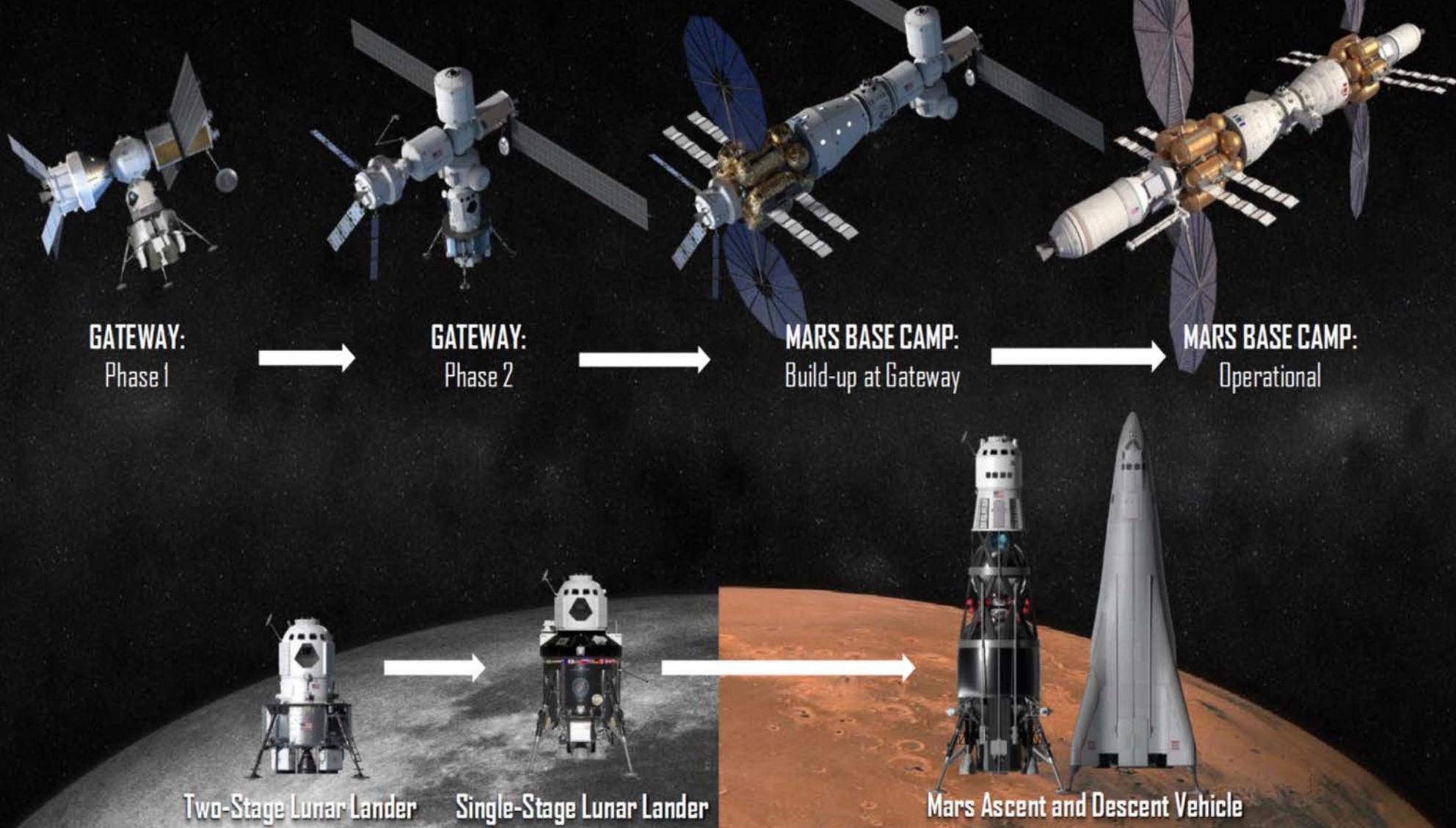
by Alan Wasser

Few people today realize or remember, but a single man, Lyndon Baines Johnson, “LBJ”, is primarily responsible for both starting and ending “The Space Race”. In 1957 and 1958, Johnson, then Senate Majority Leader and leader of the Democratic political opposition to Republican President Dwight Eisenhower, created such a controversy over the USSR’s launch of Sputnik that Eisenhower was forced into a public space race he didn’t want. That race led to the amazing accomplishments of the next ten years, including the first human landings on the Moon.

Almost a decade later, Johnson was forced to virtually shut down the program he had worked so hard to sell to the government and to the public. By 1966 and 1967, Johnson, then President, desperately needed to cut expenditures to pay for the escalating Vietnam War. So he proposed to the leaders of the Soviet Union that they agree to a treaty, which became the 1967 Outer Space Treaty, to eliminate the key prizes to be won in the space race, especially the right of either nation to claim the Moon. That allowed both sides to move expensive space development to the back burner—where it has stayed ever since.

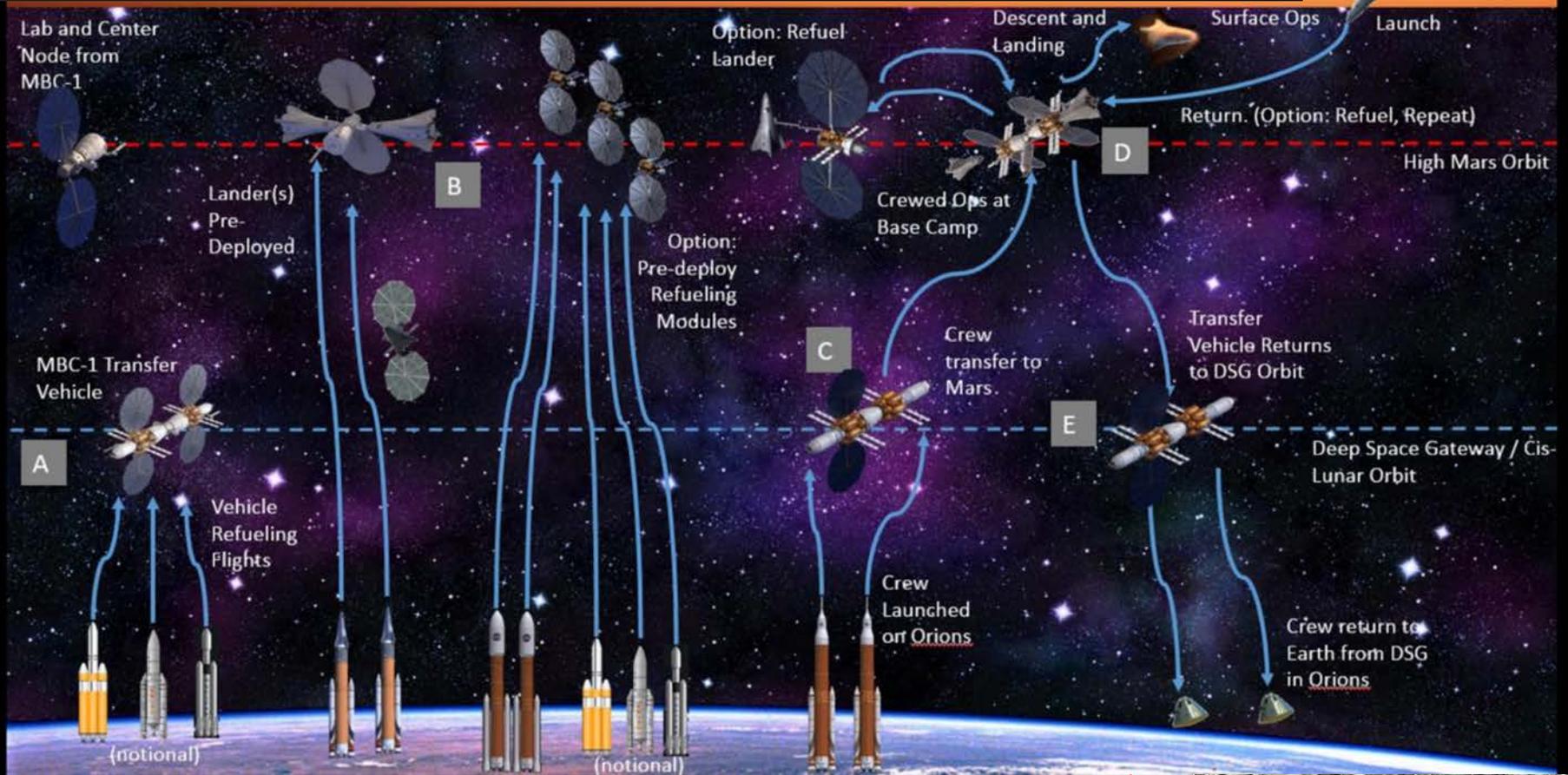
The official story - dream?

The Architecture



Space Force = new military-industrial complex?

Lockheed Martin's Mars Design Mission Architecture



Cajing! Cajing!



Mars HE Cost Reality - \$1T?

- ISS (6 crew, 391 mt, 388 m³ habitable vol., 84 kWe)¹ at ~\$150B² was not easy...but it was straightforward (\$384,000/kg)
- A ~4kg sample robotic return of ~\$8.5B³ scales to ~\$850B⁴
 - Humans are “softer” than electronics (to radiation), less acceleration tolerate, and require more expendables (air, food, and water) and living space – so this is likely a lower limit
- Is “Mars Direct” really feasible at \$100B considering all the technical challenges?
 - Our answer is NO! – not if development and all infrastructure costs are included
 - Also the Mars Transfer Vehicle(s) will require ~5 km/s of propulsion each way from Low-Earth Orbit
- To change the speed of 400 mt of an MTV by 7 km/s (assume it is “thrown away” at return requires ~480 mt of LH2 for a nuclear thermal propulsion (NTP) system (900s Isp) or ~1480 mt of LH2 + LOX; at \$50k/kg the cost differential alone for launch from Earth is ~10⁶ kg x \$50k/kg = \$50B, but with larger tanks and structure the vehicle mass would go up significantly as well
 - Development and forward pre-positioning cost for ISRU production of propellant is unknown
- ¹ International Space Station Facts and Figures, NASA, http://www.nasa.gov/mission_pages/station/main/onthestation/facts_and_figures.html
- ² Costs of US piloted programs, Claude Lafleur, *The Space Review* (2010) <http://www.thespacereview.com/article/1579/1>
- ³ *Vision and Voyages for Planetary Science*, NAS (2011): summed CATESs for MAX-C descender (\$2.4B) + MSR Lander & MAV (\$4.0B) + MSR Orbiter & EEV (\$2.1 B)
- ⁴ Orion MPV crew module is 8.8 mt landing weight for crew of 4 and return payload of 100 kg http://www.nasa.gov/pdf/617408main_fs_2011-12-058-jsc_orion_quickfacts.pdf - hence ~400 kg return mass

It's not about the \$\$\$, it is whether we have the will to go...

John Grunsfeld
small, light, nimble
approach

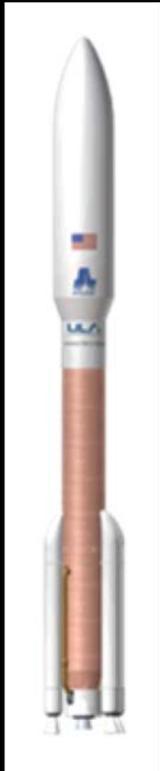
Consider a conjunction class
orbital Mars mission:

Transportation 10 x \$350M = \$3.5B

Payloads 10 x \$1B = \$10B

Crew transport 1 x \$500M = \$0.5B

Total: \$14B x 2 = \$28B

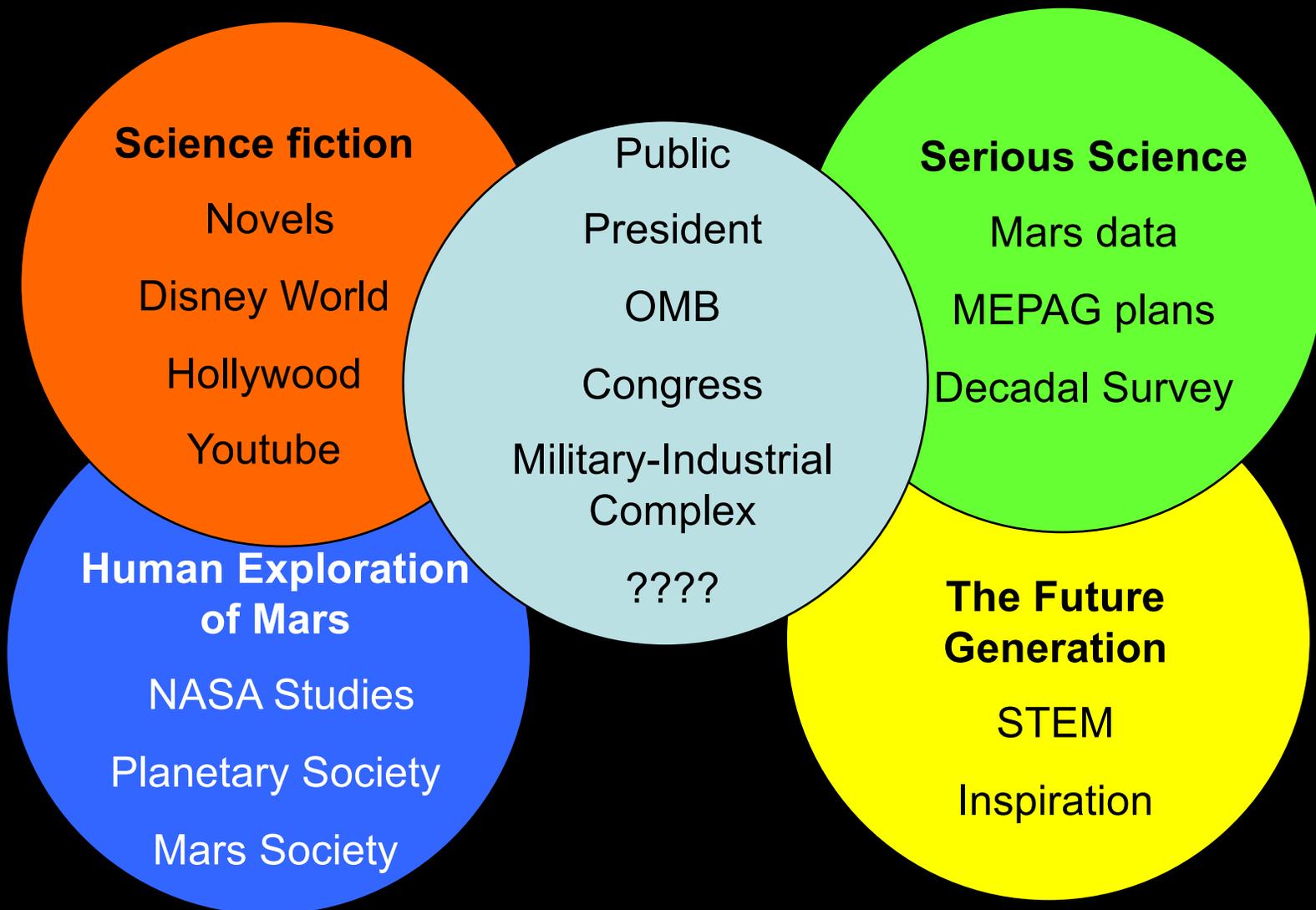


NASA Spends \$4B/year on "exploration"

IN 7 YEARS WE COULD FUND
A MISSION TO MARS

And have a full backup to fly a second mission
26 months later if all the rockets work!

The root cause of the dilemma – Confusion amongst the stakeholders who want mission to Mars



Human Exploration Moon & Mars

The Issues:

- Will the lunar program grow and suck up all funds, preventing ever getting to Mars? The companies building the big space stations are not so interested in destination – just keeping the money flowing.
- Could a small, nimble, bolder mission to Mars work? It's an awfully long way to go....
- How will HE programs be funded? NASA? International? Private?
- Note that there is actually plenty of \$\$ in the US.....



Back of Envelope Calculations

NASA's MAVEN mission to Mars cost ~\$800 million. How much is this per taxpayer?

Number of taxpayers ~ 130M

$\$800M / 130M$ taxpayers
= \$5.50 each



How much does the US spend on high-heeled shoes per year?

Cost of shoes – let's guess \$50/pair

Population = 300 M

How many shoes bought?

High guess = 150M

total = $150M \times \$50 = \$7.5 B$

Low guess = 20M

total = $20M \times \$50 = \$1B$

Equivalent to 1-10 MAVENS/year!

**America spends
\$300 million on
halloween
costumes for pets**



<http://www.marketwatch.com/story/has-halloween-gone-to-the-dogs-and-guinea-pigs-2013-10-25>

*How do we harness
this wealth for
space exploration?*

Public Opinion Polls

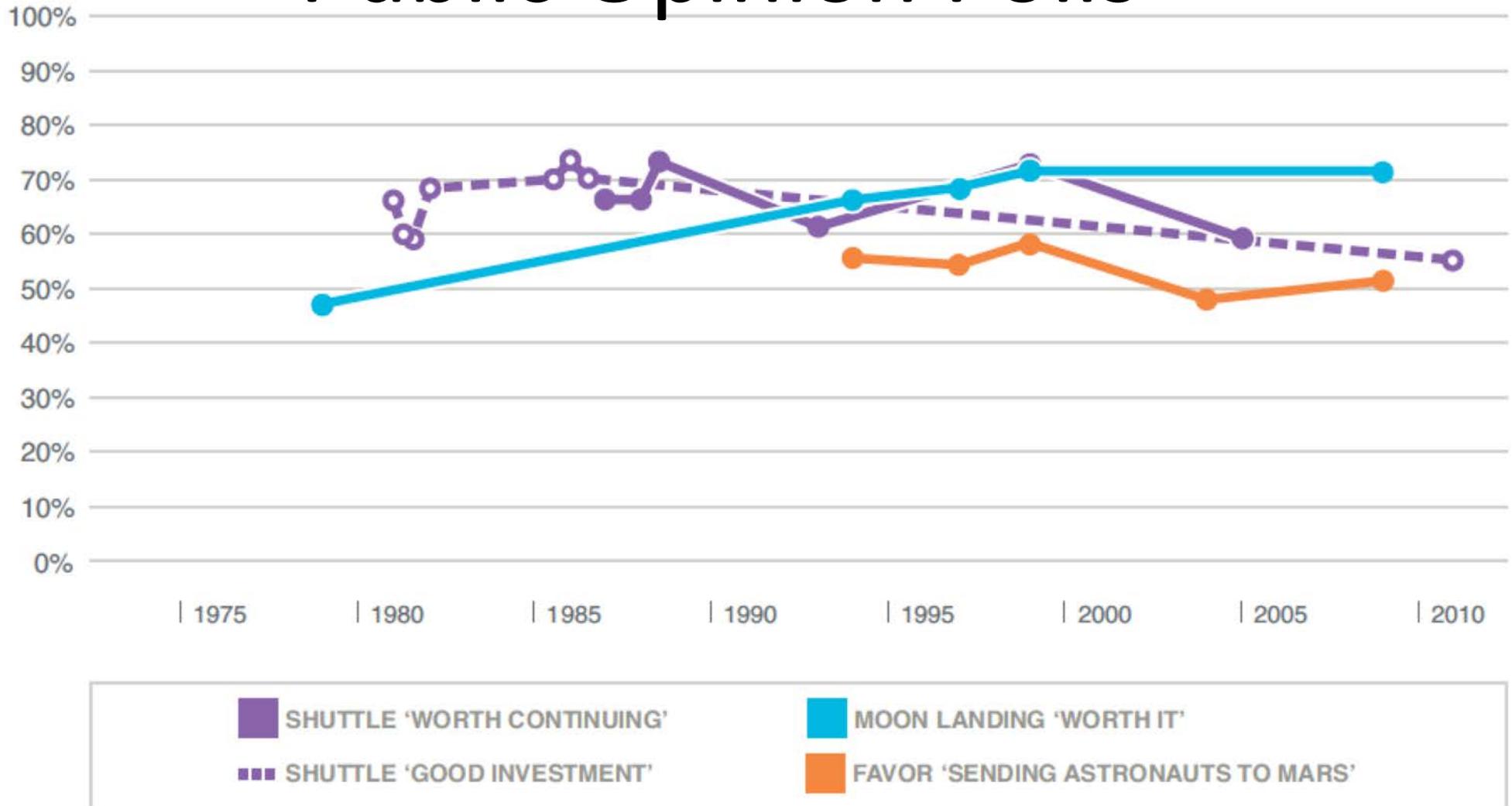
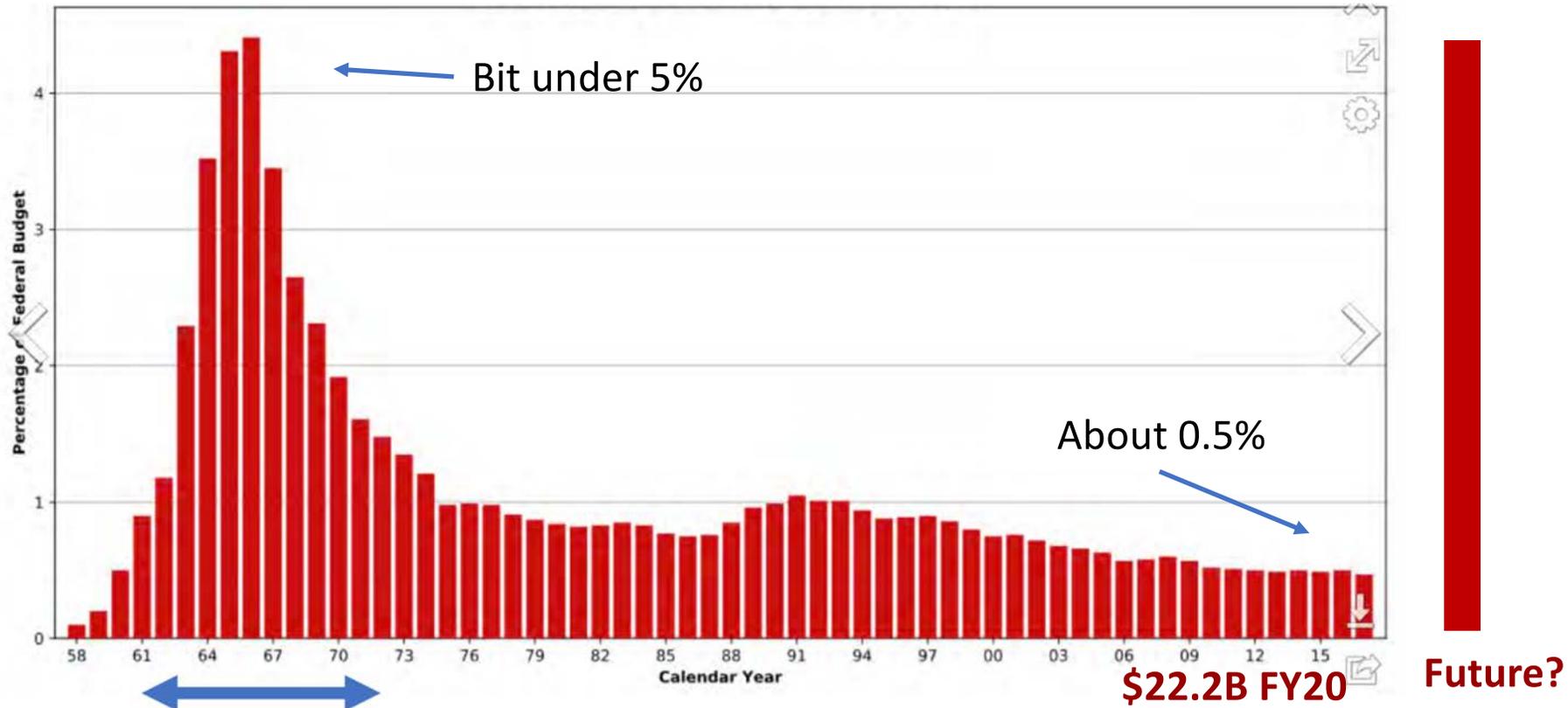


FIGURE 1.8 Public support for the space shuttle, Moon landing, and Mars mission, 1979-2011. SOURCE: Shuttle continuation: CBS News and New York Times; Shuttle investment: NBC News; Moon landing: CBS News; Mars: CBS News.

*What's the current public opinion?
Fund space or climate change?*

NASA budget as Percentage of Federal Budget



Options:

- Raise by factor 10 to 5% = \$222B/yr – *now you're talking!*
- Raise by factor 2 and go international
- Find cheaper, faster, bolder way to go – Zubrin, Grunsfeld
- Let the billionaires pay
- Send robots instead

Future of Human Exploration?

What's changed since Apollo:

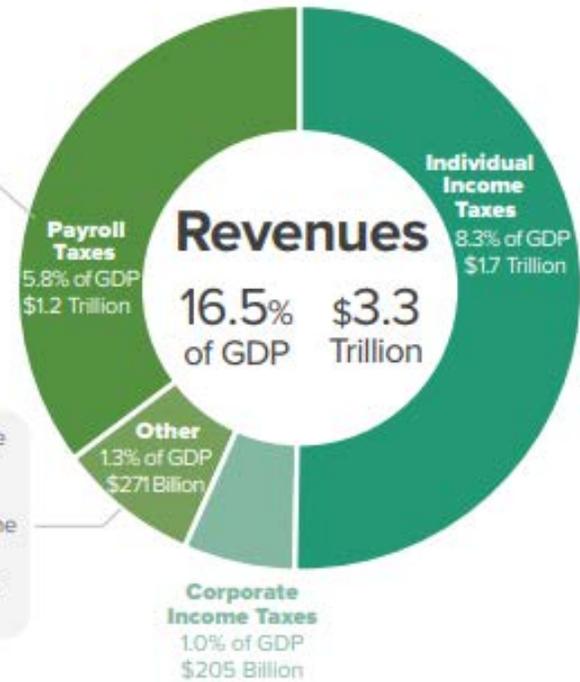
- No cold war
- Capabilities of robots – cameras, computers, lightweight, autonomous, etc.

Fran's Opinion:

- There's nothing humans can do better than robots in space – except tourism
- Taxpayers should not pay for tourism
- Alternatively, give every child goggles and gloves – and let them explore virtual space – using images from thousand of robots around the solar system
- *Article from Nautilus magazine where I make some more controversial statements about human exploration <http://nautil.us/issue/51/limits/beyond-voyager>*

Extras

THE FEDERAL BUDGET IN 2018

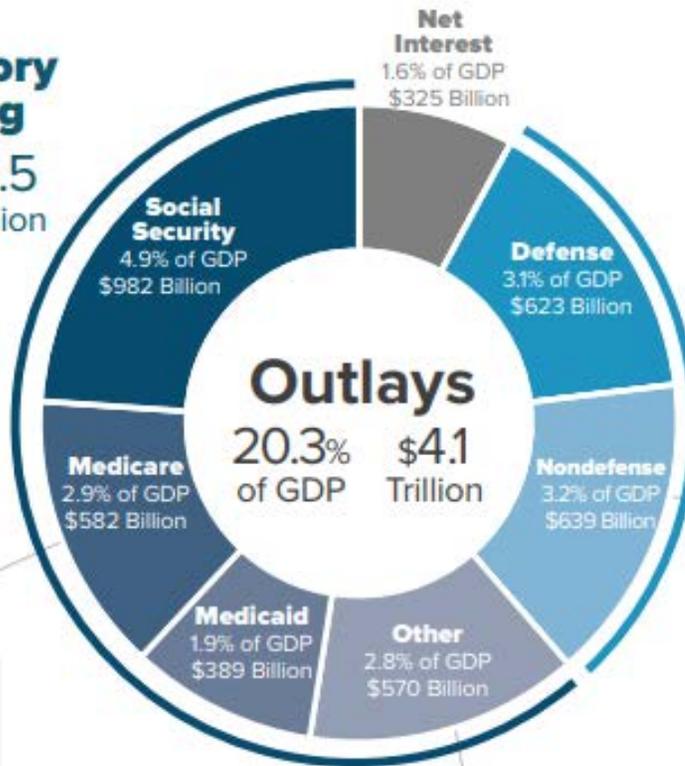


Taxes that fund social insurance programs, primarily Social Security and Medicare's Hospital Insurance program

Excise taxes, estate and gift taxes, customs duties, remittances from the Federal Reserve, and miscellaneous fees and fines

Mandatory Spending

12.5% of GDP
\$2.5 Trillion



Outlays for Medicare minus income from premiums and other offsetting receipts

Outlays for unemployment compensation, federal civilian and military retirement, some veterans' benefits, the earned income tax credit, the Supplemental Nutrition Assistance Program, and other mandatory programs, minus income from offsetting receipts

Discretionary Spending

6.2% of GDP
\$1.3 Trillion

Outlays for many programs related to transportation, education, veterans' benefits, health, housing assistance, and other activities

Federal Revenue % by Tax

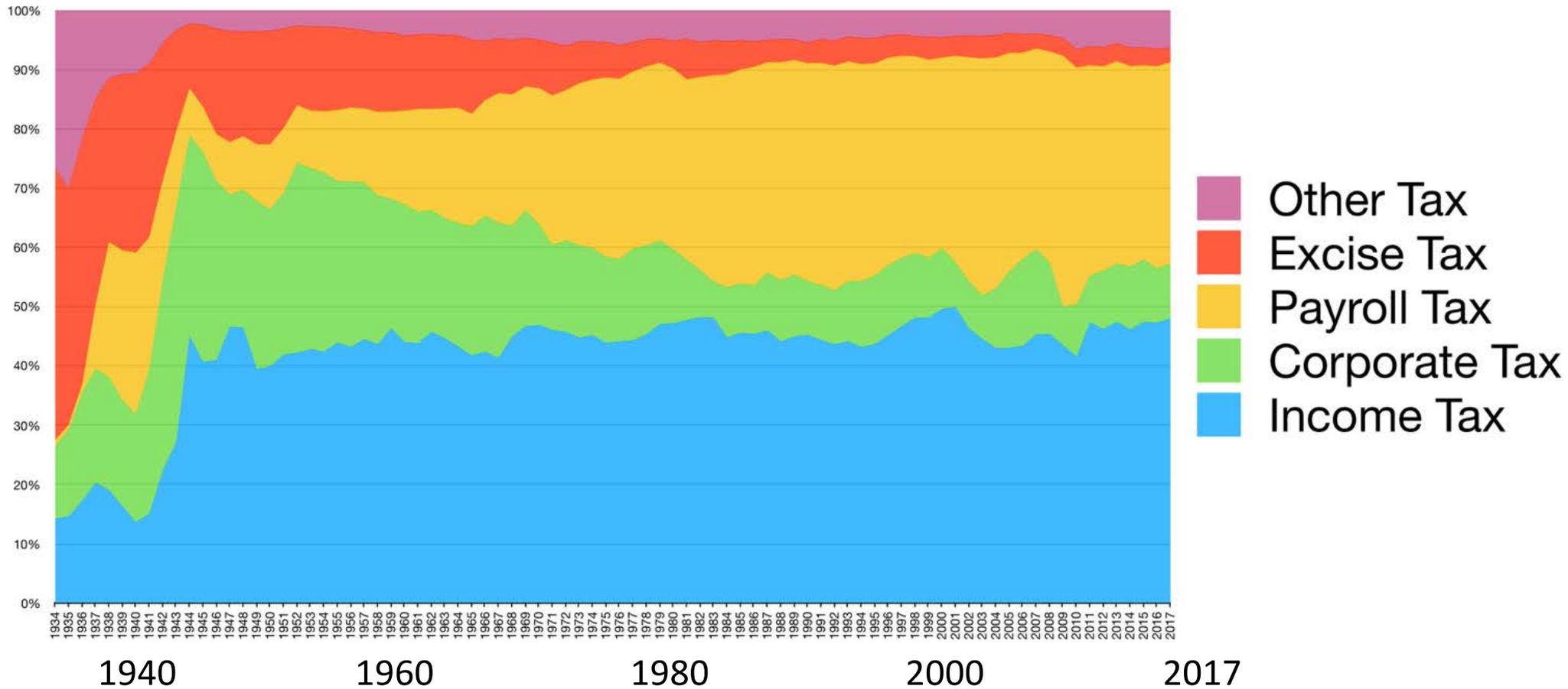
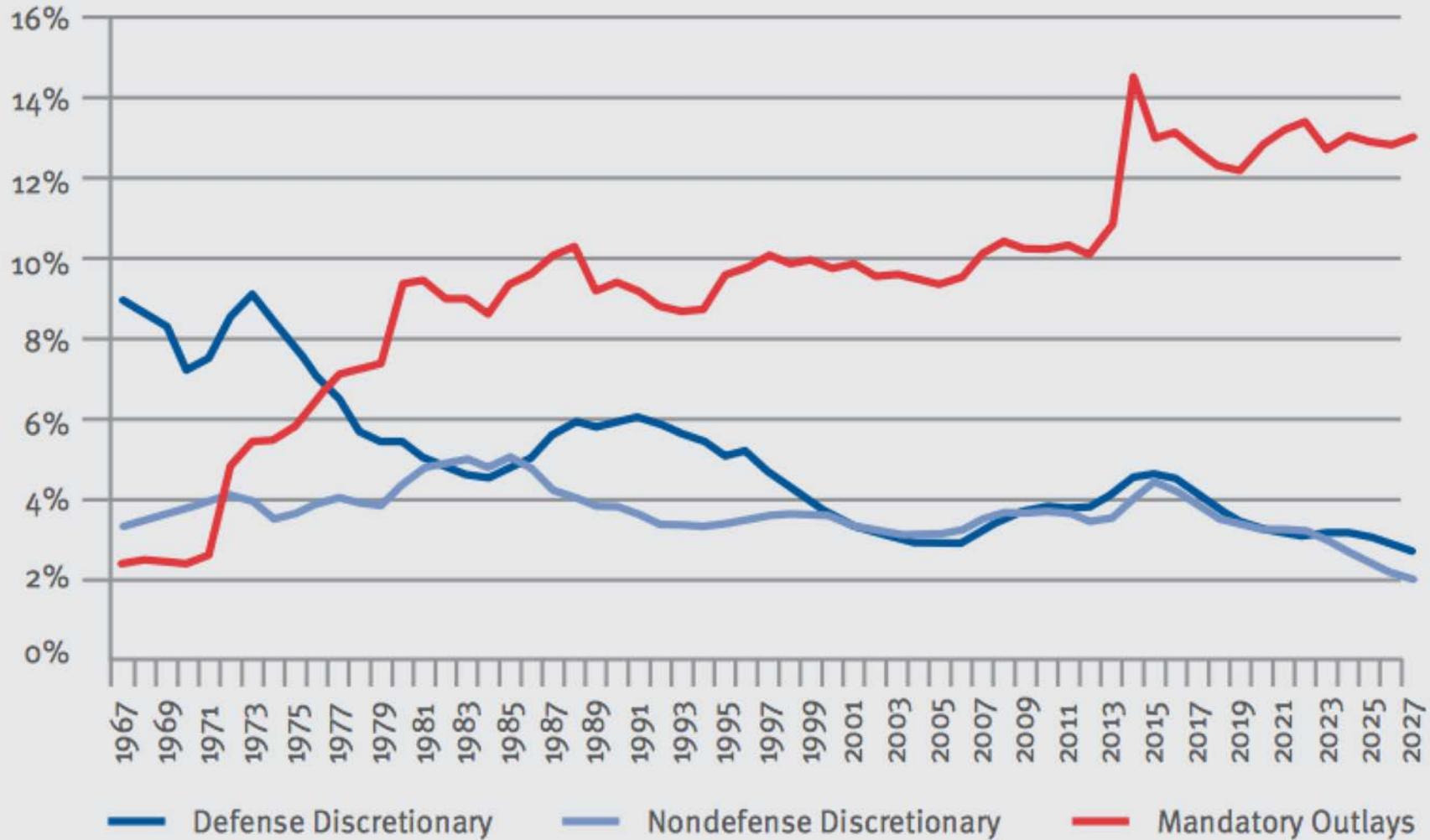
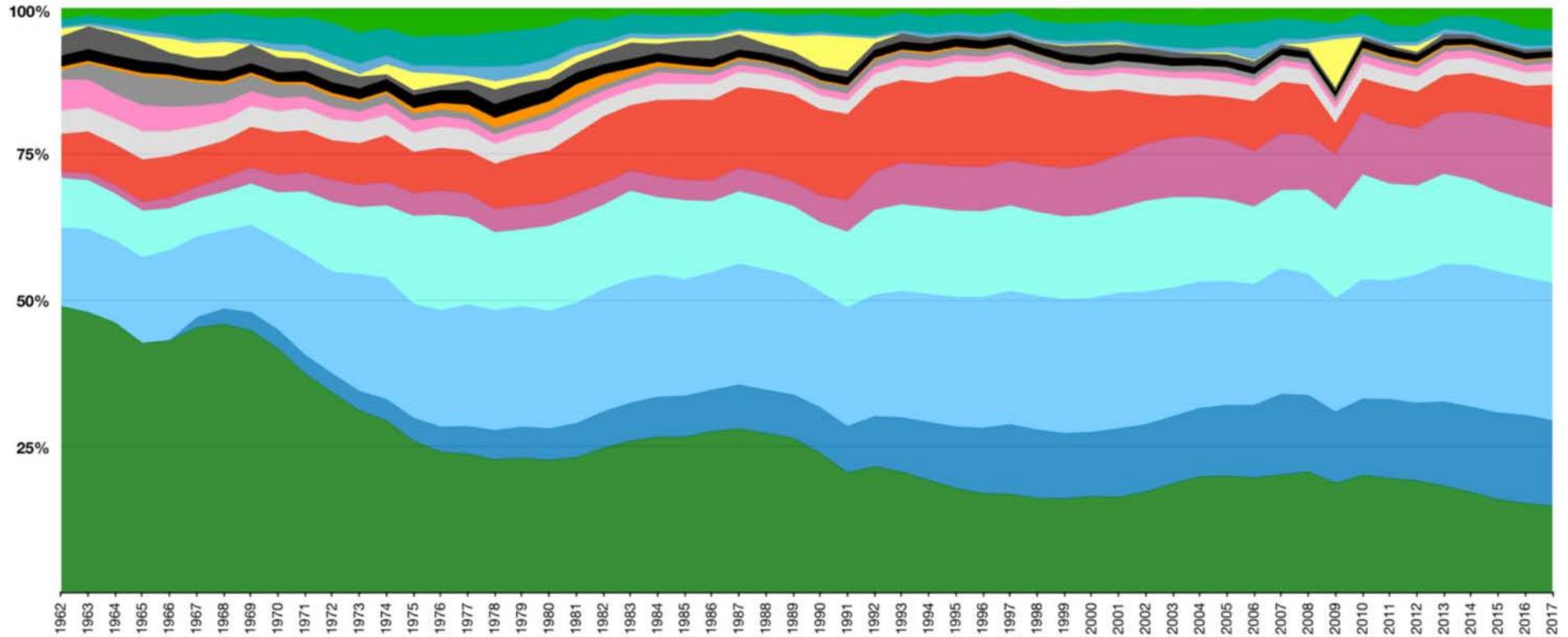


Figure 4: Federal Outlays as a Share of GDP



ed States Government, FY 2018. © 2017 AAAS

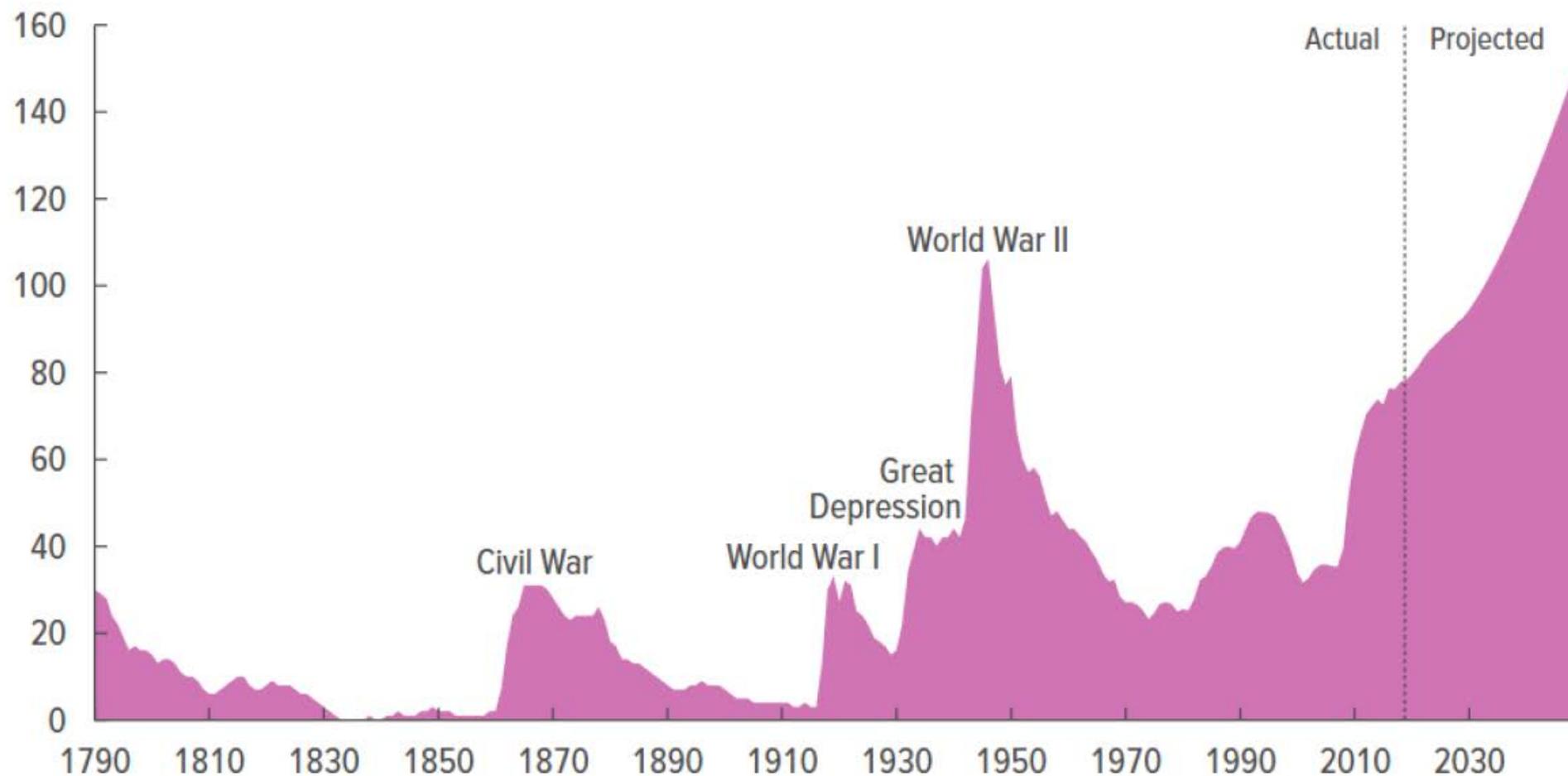
Federal Government Outlays (percentage)



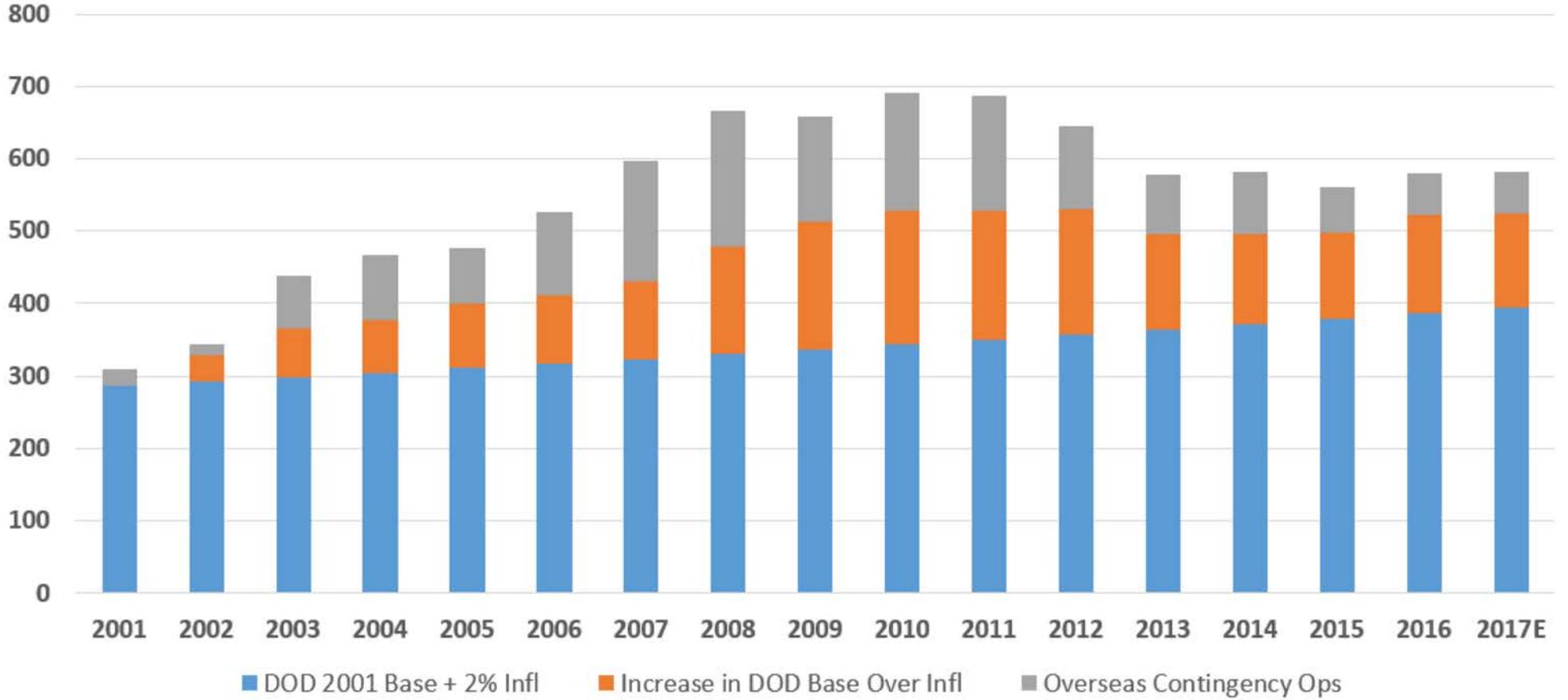
- Veterans Benefits and Services
- Education, Training, Employment, and Social Services
- Community and Regional Development
- Commerce and Housing Credit
- Agriculture
- Natural Resources and Environment
- Energy
- General Science, Space, and Technology
- International Affairs
- Transportation
- Net Interest
- Medicaid
- Income Security
- Social Security
- Medicare
- National Defense

Debt Held by the Public

Percentage of Gross Domestic Product



U.S. Defense Spending Trends 2001-2017 (\$ Bil)



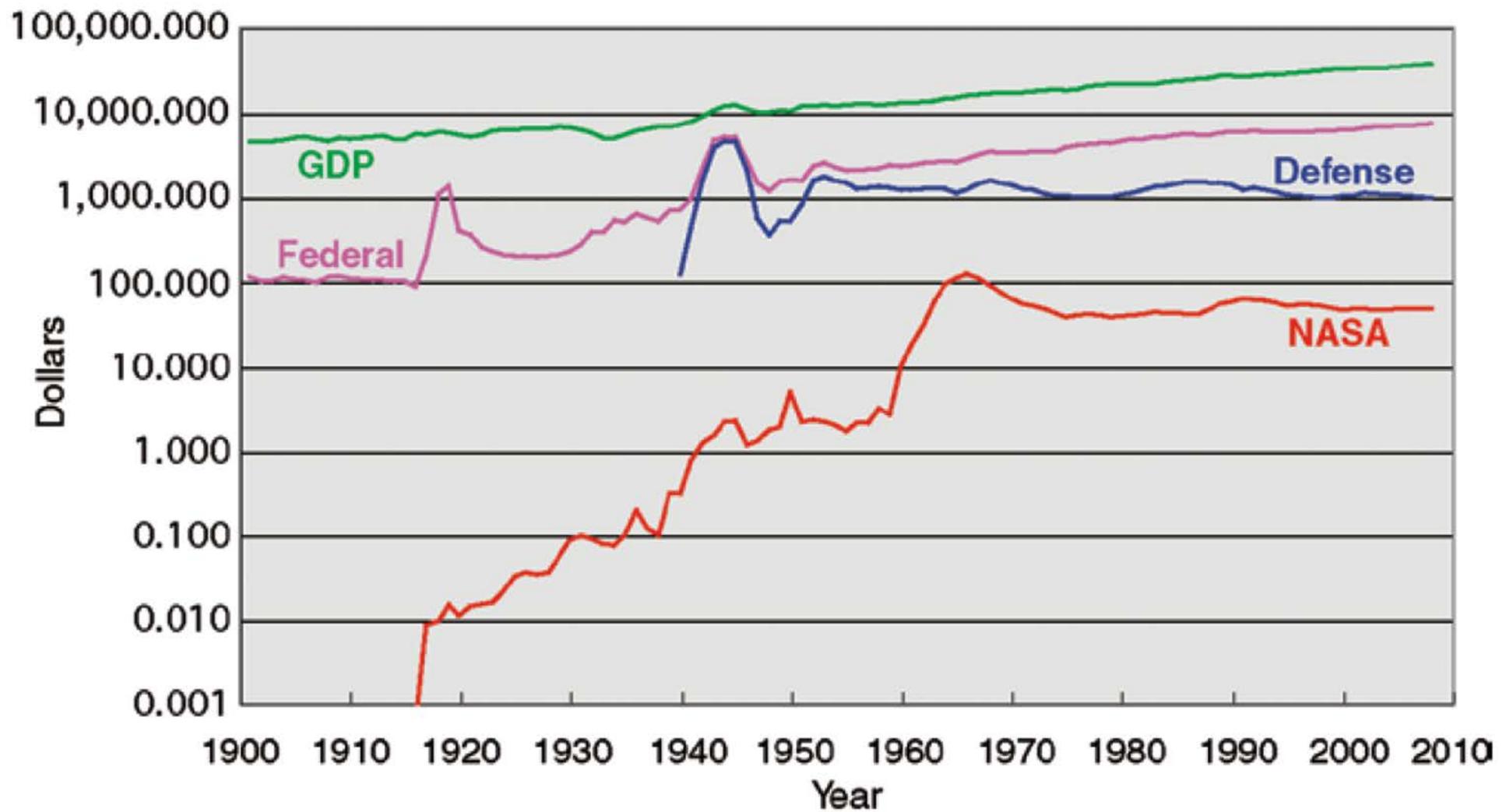
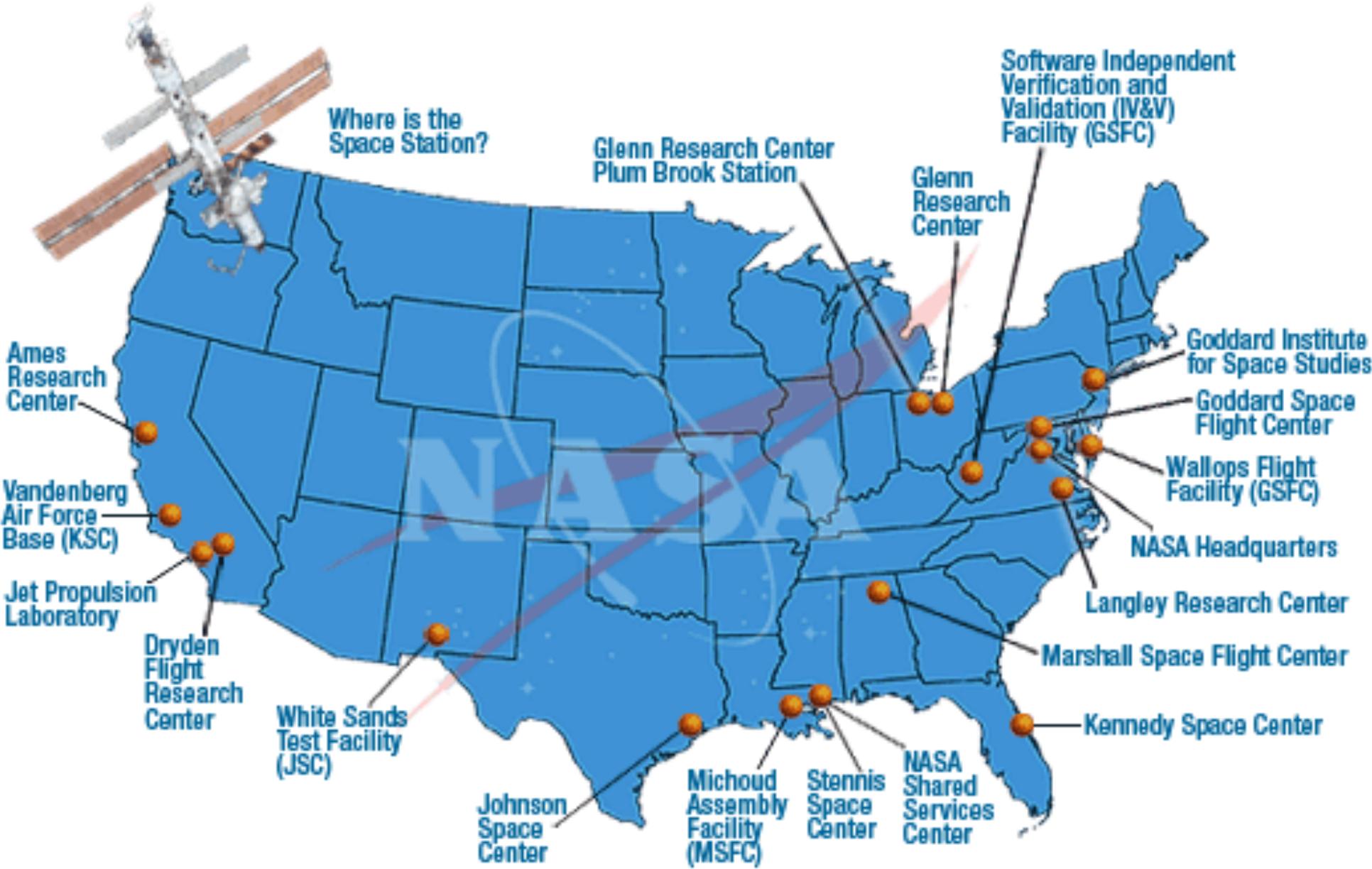


Figure 4. Comparison of fixed-year (1996) costs per capita. National Advisory Committee on Aeronautics (NACA) and NASA budgets on a per capita basis are combined. The NACA budget is for the years 1915–1959; NASA was formed in 1959. All budgets are based on actual figures from 1901 or later until 2002, and projections are from 2003–2008.

NASA Centers



Planetary Science Missions

Moon & Mars Missions

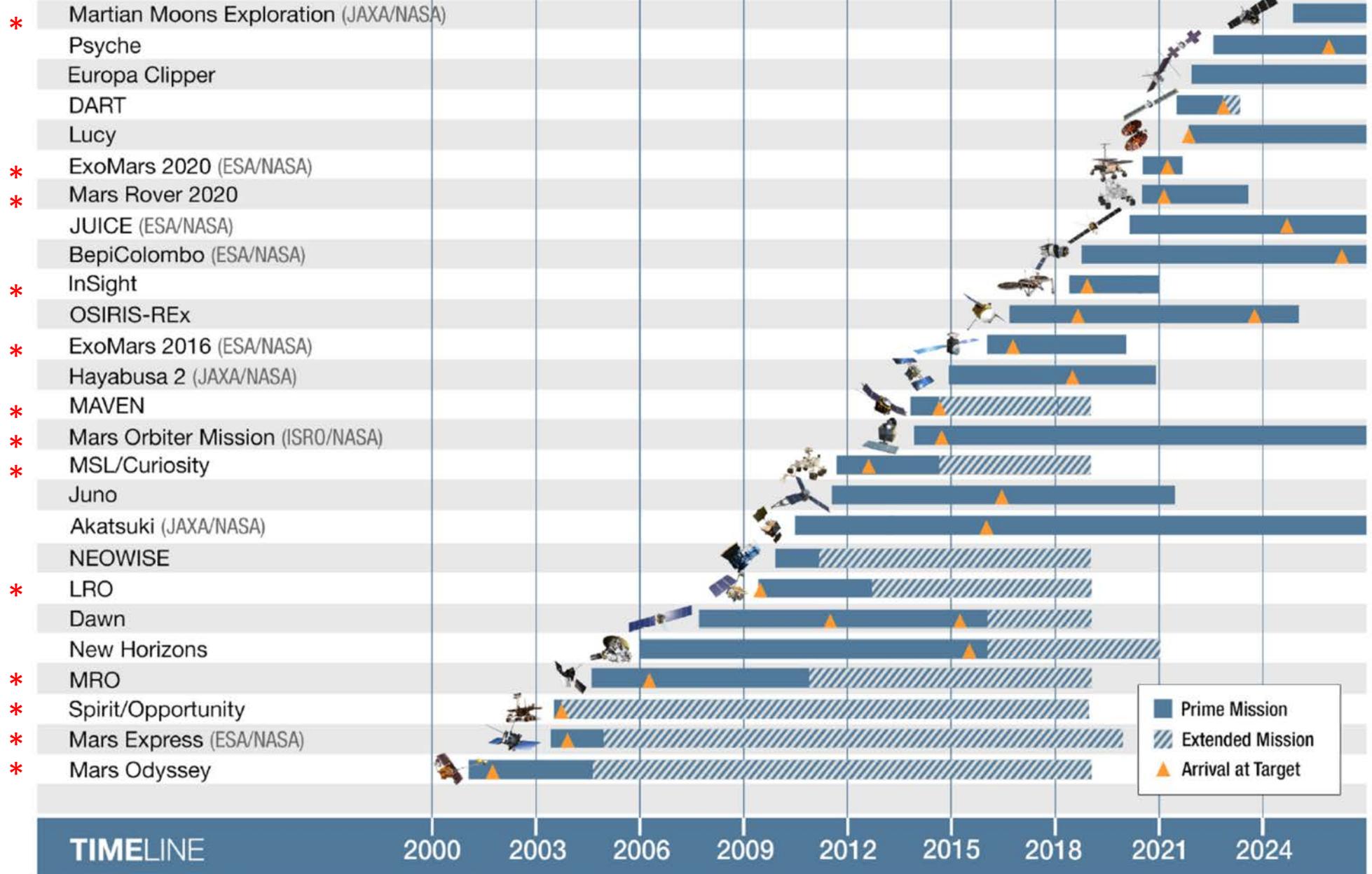


FIGURE S.1 Recent, current, and in-development NASA planetary science missions and international missions which NASA is participating. SOURCE: NASA.