

# Lessons learned from (and since) the Voyager 2 flybys of Uranus and Neptune

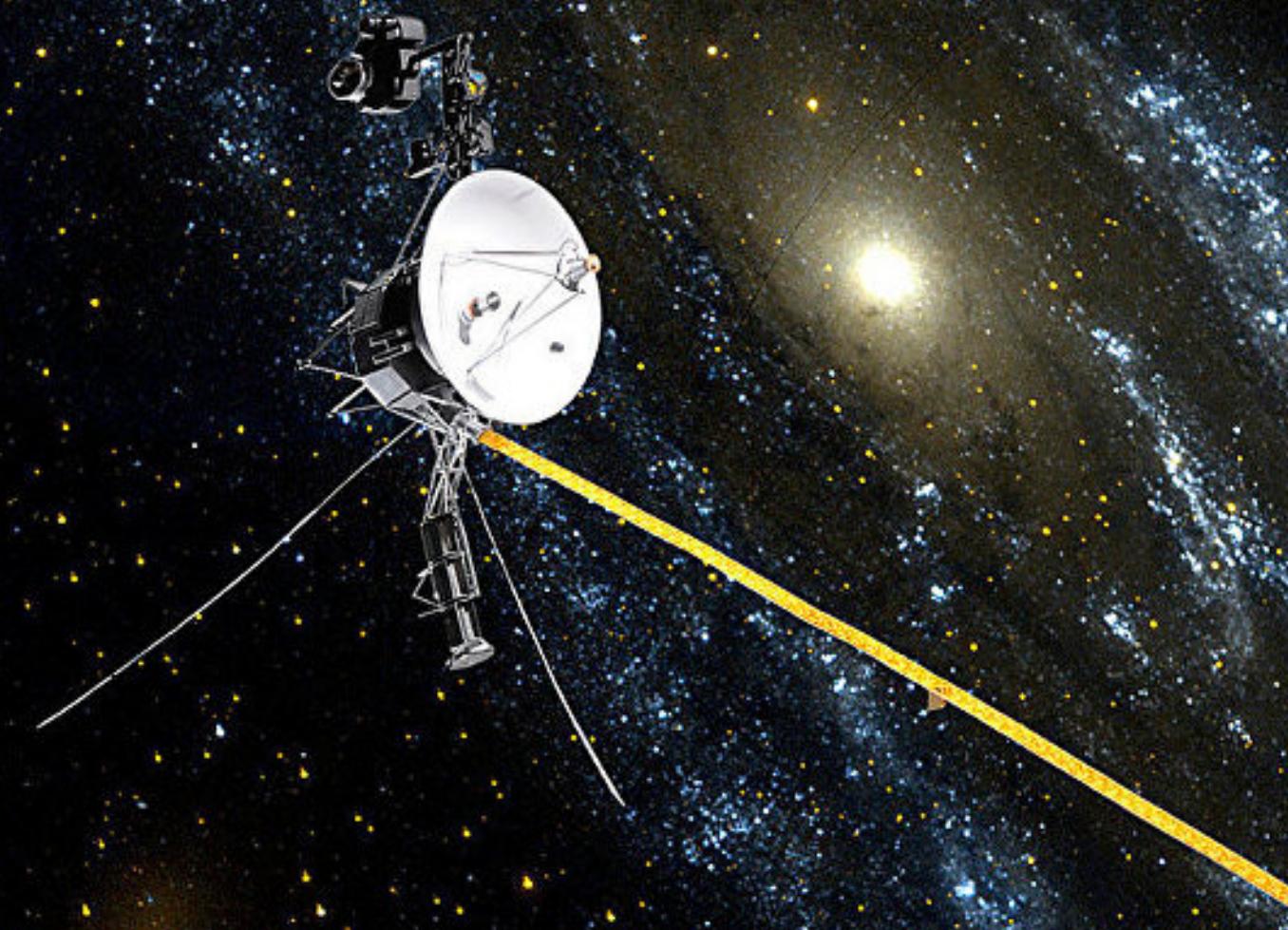


Heidi B. Hammel  
 [@hbhammel](https://twitter.com/hbhammel)



Images: NASA/JPL  
Voyager 2 in August 1989

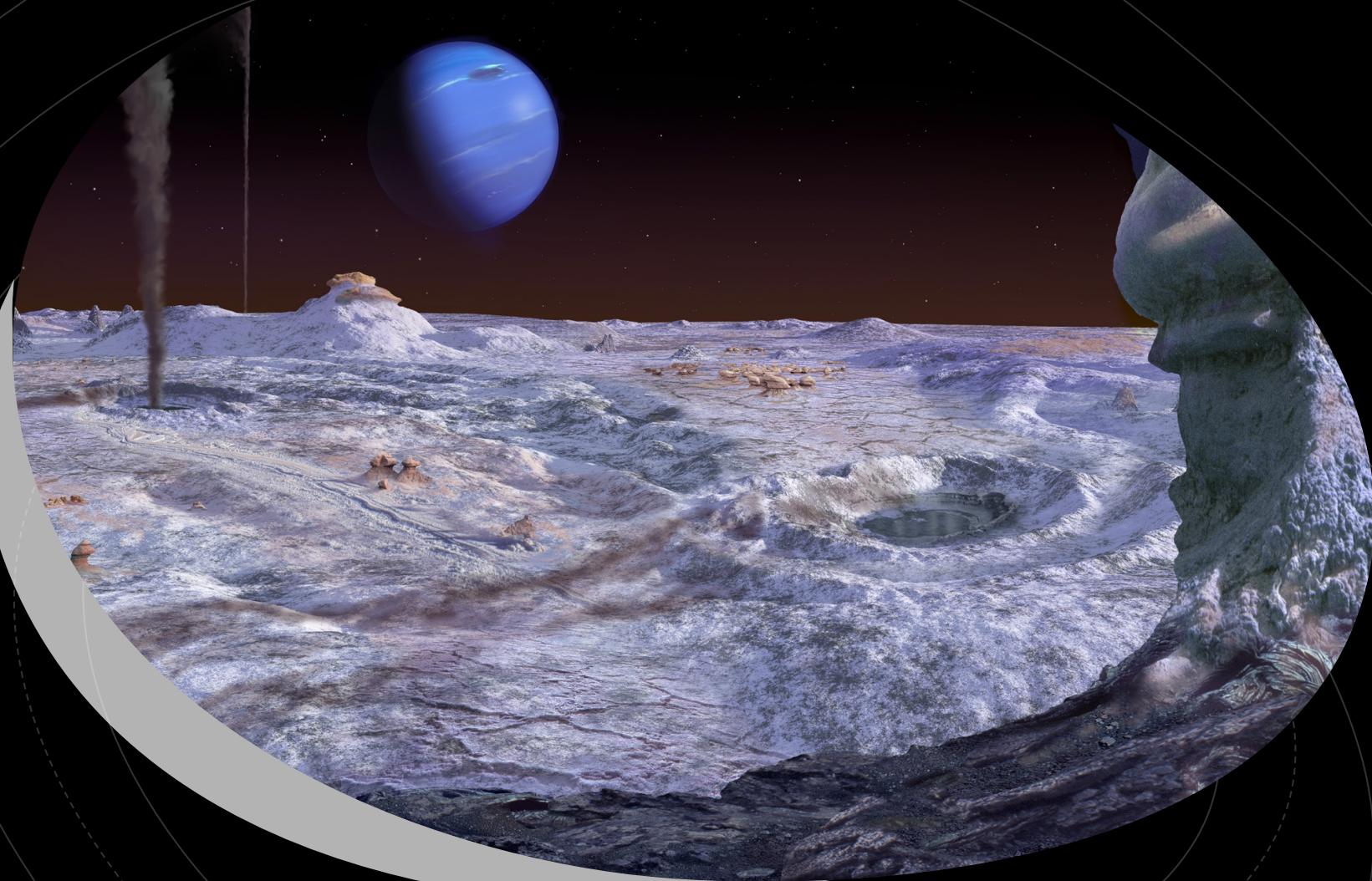
Some lessons from the past bear repeating,  
lest we forget them...





# An important lesson from *Michelangelo*

"The greatest danger for most of us  
is not that our aim is too high  
and we miss it,  
but that it is too low  
and we reach it."



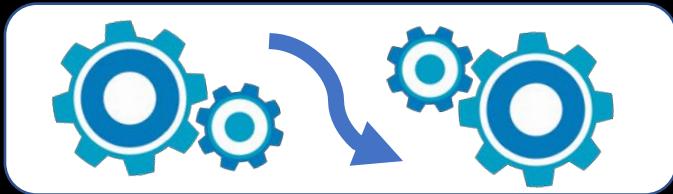
#UranusAndNeptuneLetsGoBack #ItsTime

# Lesson 0

When your mission costs above \$1B,  
science is necessary but *not sufficient*

# Some more lessons

Process



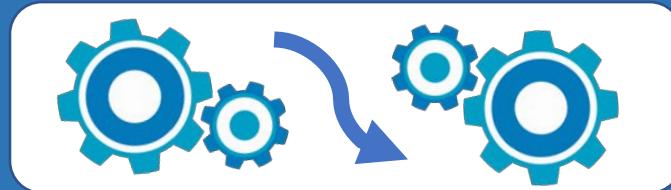
Planning



People



# Process



# Planning



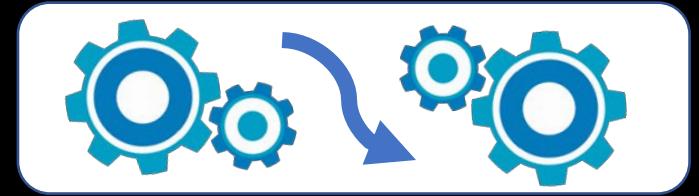
# People



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# Process



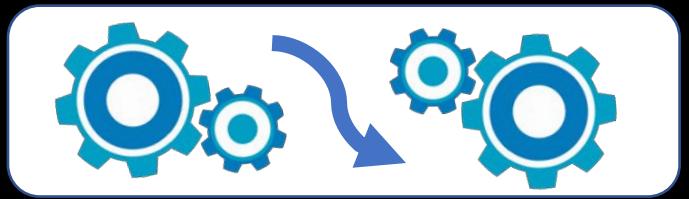
Be open to new concepts

New technology

Innovative development processes

Miscellaneous

# Process



## New technology

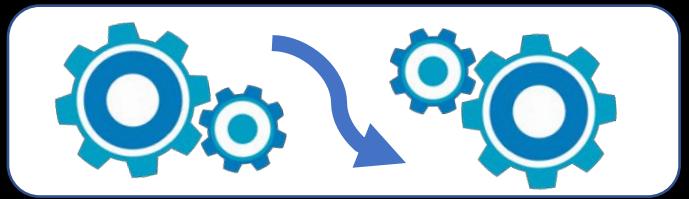
Yes, yes: evergreen, perennial, ongoing

Reminder: awesome presentations & posters!

Remarkable array of technology expertise

Crucial for success; push on this

# Process



Innovative development processes

Cassini "Market" Strategy

# Cassini Resource Exchange

Task: Ensure 12 science instruments built within 4 years for \$200M

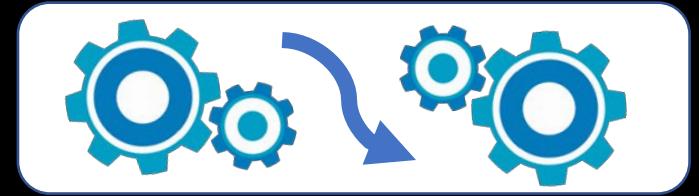
Solution: Market-based systems

Initially, data rate, budget, mass, and power were traded; dollars added later to help with phasing issues

Science instrument manager had veto power

Program WAS able to build and deliver all instruments on time; overall cost of the science payload grew by <1%; science payload mass shrank by 7%

# Process



Innovative development processes

Cassini "Market" Strategy

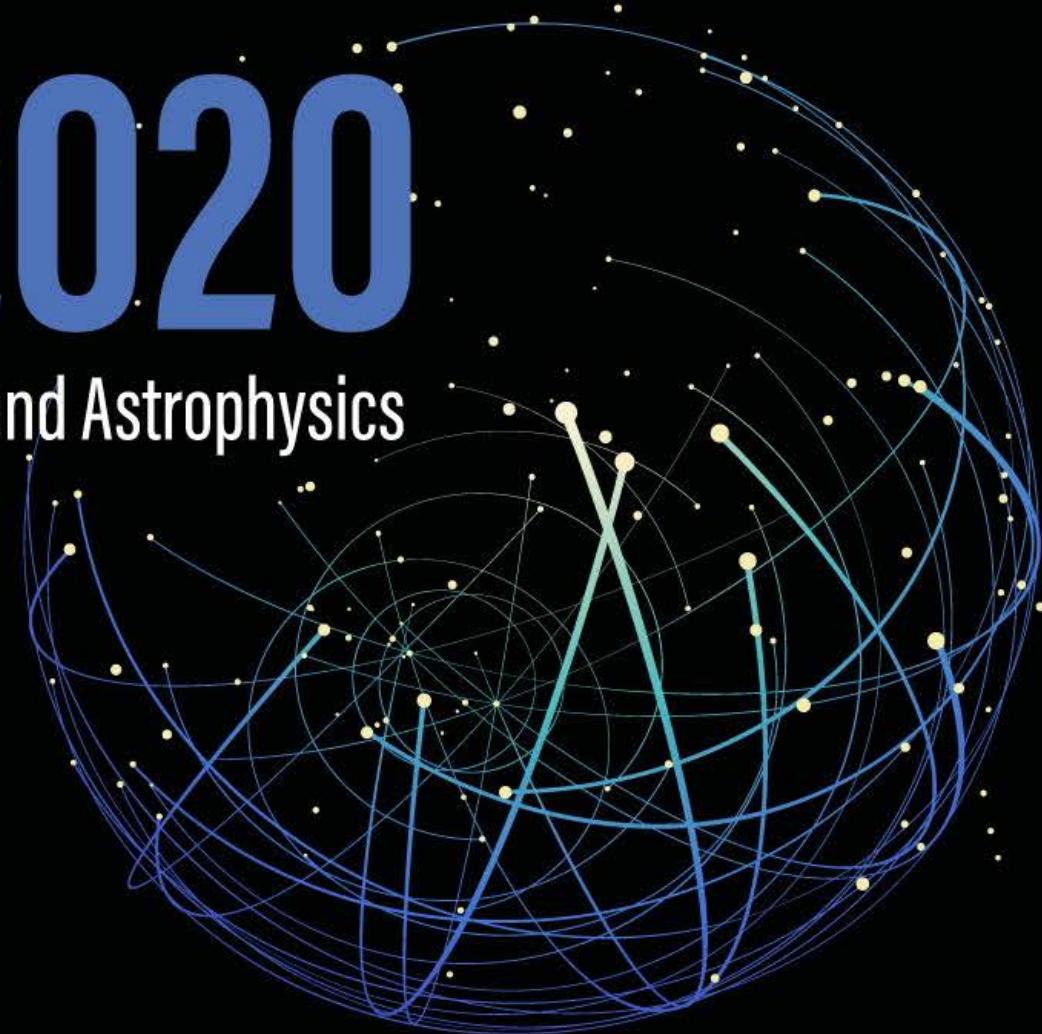
Astrophysics Flagship Cost Considerations

# Astro 2020

Decadal Survey on Astronomy and Astrophysics

*The National  
Academies of*

SCIENCES  
ENGINEERING  
MEDICINE





# Strategies for change for cost- and schedule-efficient project management based on research

\* Bitten, R., et al., 2019, Challenges and Potential Solutions to Develop and Fund **NASA Flagship Missions**, IEEE, 978-1-5386-6854-2/19  
(\* = Strongly recommended reading)

Wiseman, J., 2015, The **Hubble Space Telescope** at 25: Lessons Learned for Future Missions, IAUGA 2258532W

Mitchell, D., 2015, An Overview of NASA Project Management, **MAVEN** Magic, and Lessons Learned

Martin, P., 2012, NASA's Challenges to Meeting Cost, Schedule, and Performance Goals, OIG Report IG-12-021

\* Feinberg, L., Arenberg, J., et al., 2018, Breaking the Cost Curve: Applying Lessons Learned from the JWST Development to Build More Cost Effective Large Space Telescopes in the Future, SPIE 10698-23.

Arenberg, J., Matthews, G., et al., 2014, Lessons We Learned Designing and Building the Chandra Telescope, SPIE 9144-25

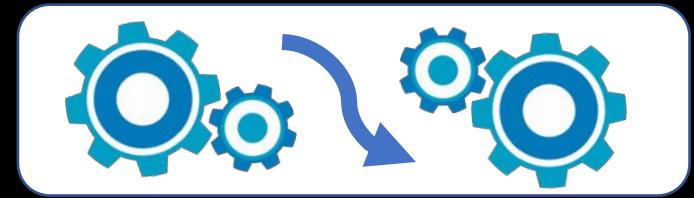
**2004-2007, Defense Procurement: Full Funding Policy – Background, Issues, and Options for Congress, CRS Report for Congress, RL31404**

**O'Rourke, R., 2006, Navy Ship Procurement: Alternative Funding Approaches – Background and Options for Congress, CRS Report for Congress, RL32776**

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# Process - MISC



## Alternative modes of operation

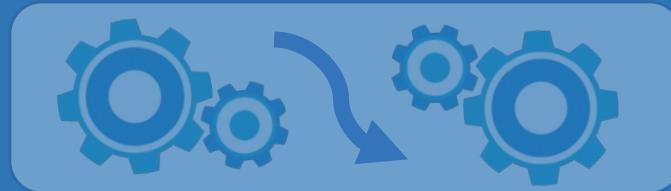
- New Horizons "sleep" for long stretches
- Team with other disciplines for off-target in-flight science (astrophysics, heliophysics)

Engage with Industry! Now!

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# Process



# Planning



# People



# Planning



Multi-decadal time scales = challenges

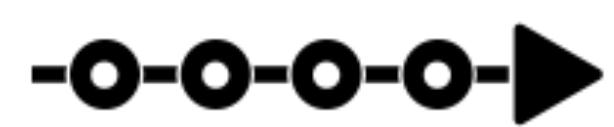
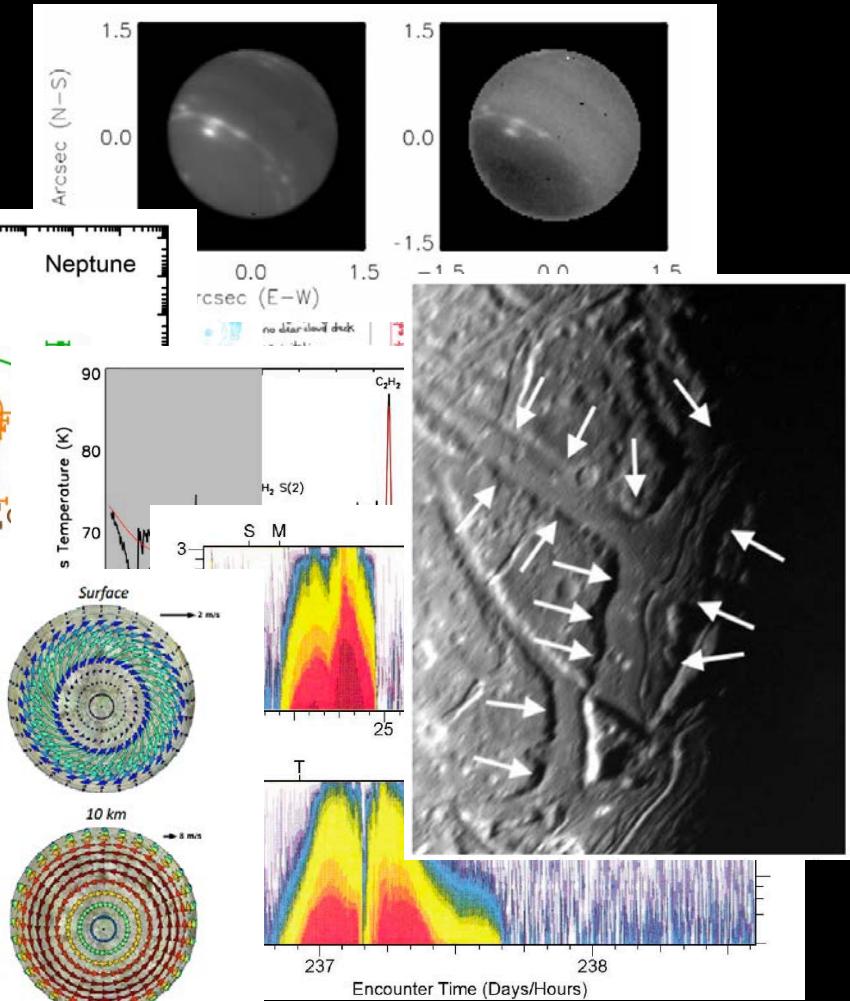
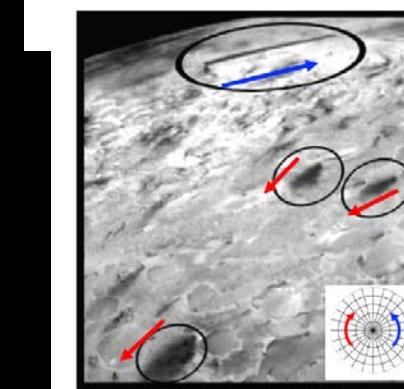
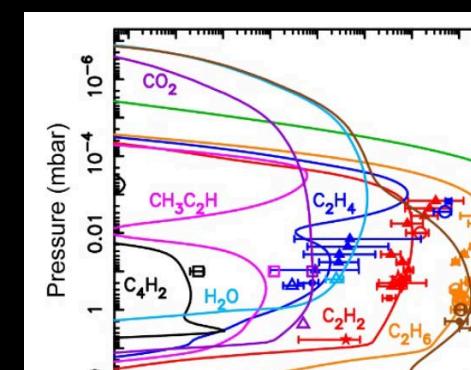
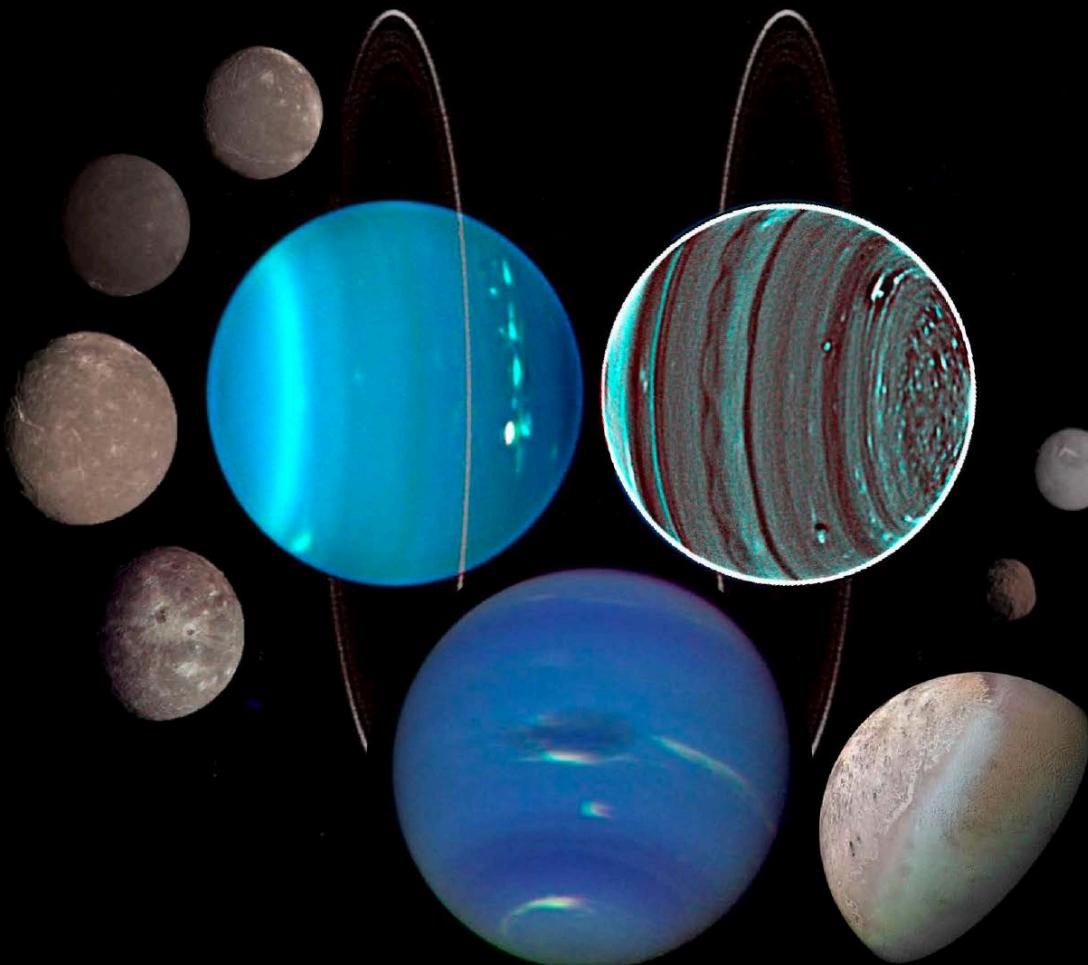
Target evolution

Planning *within* communities

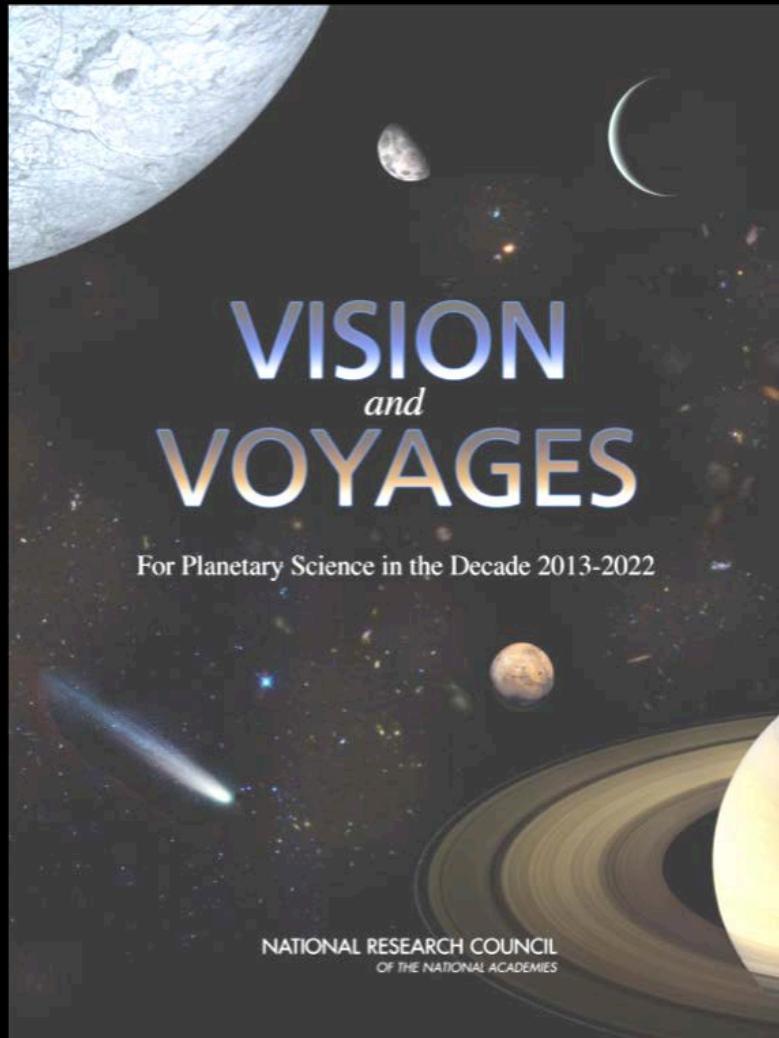
Engage with Industry

Synchronization across international borders

# Target evolution



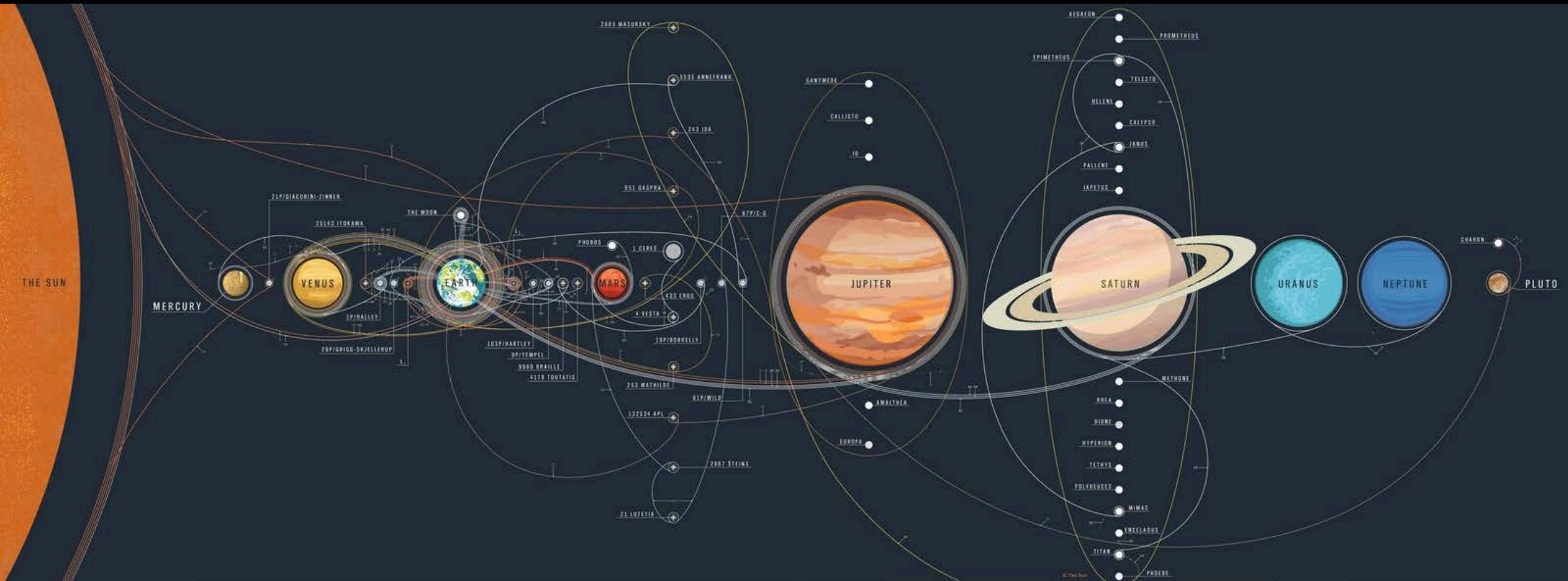
# Planning within communities



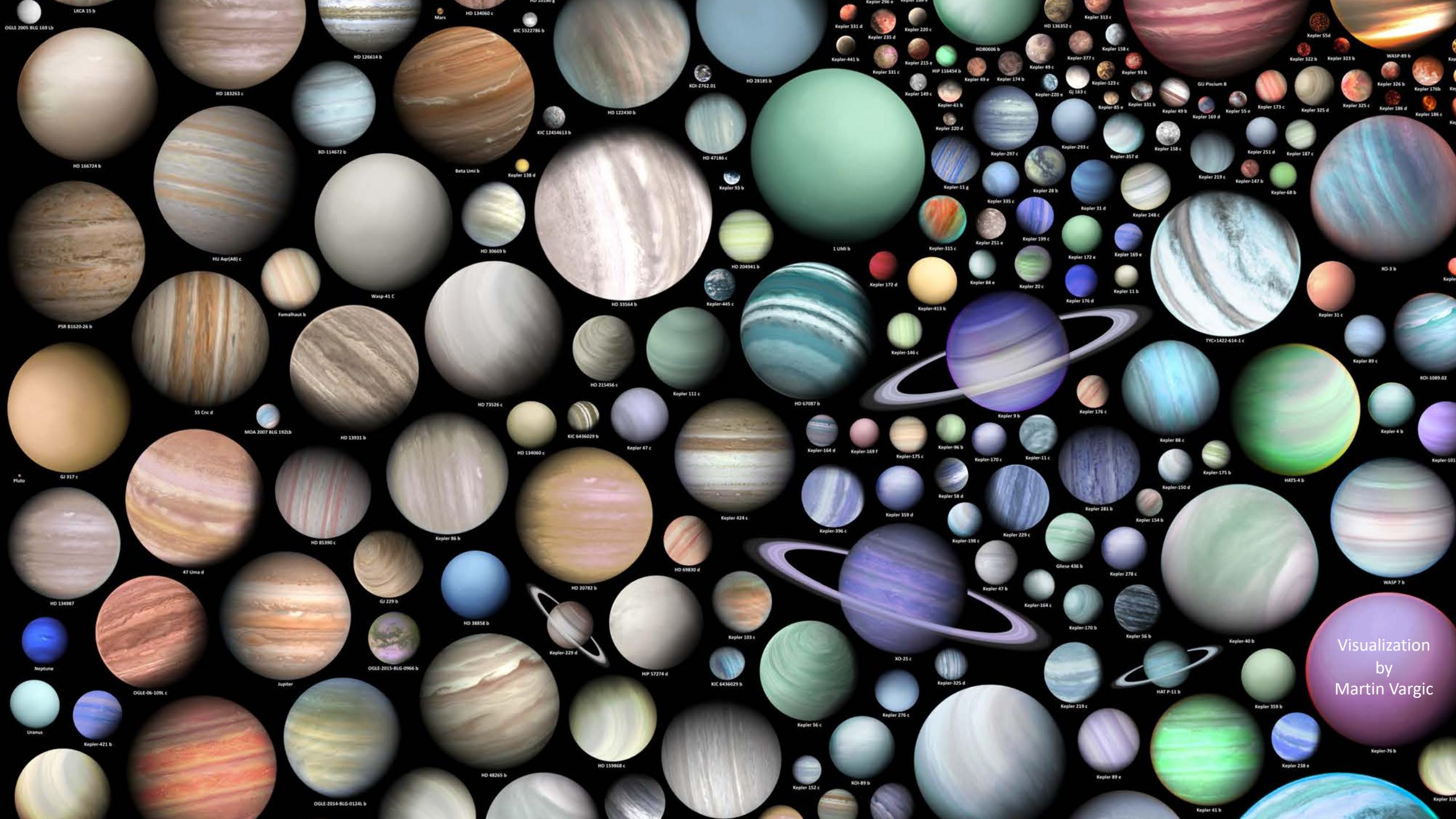
**US Planetary Decadal  
Statement of Task**

**still in process**

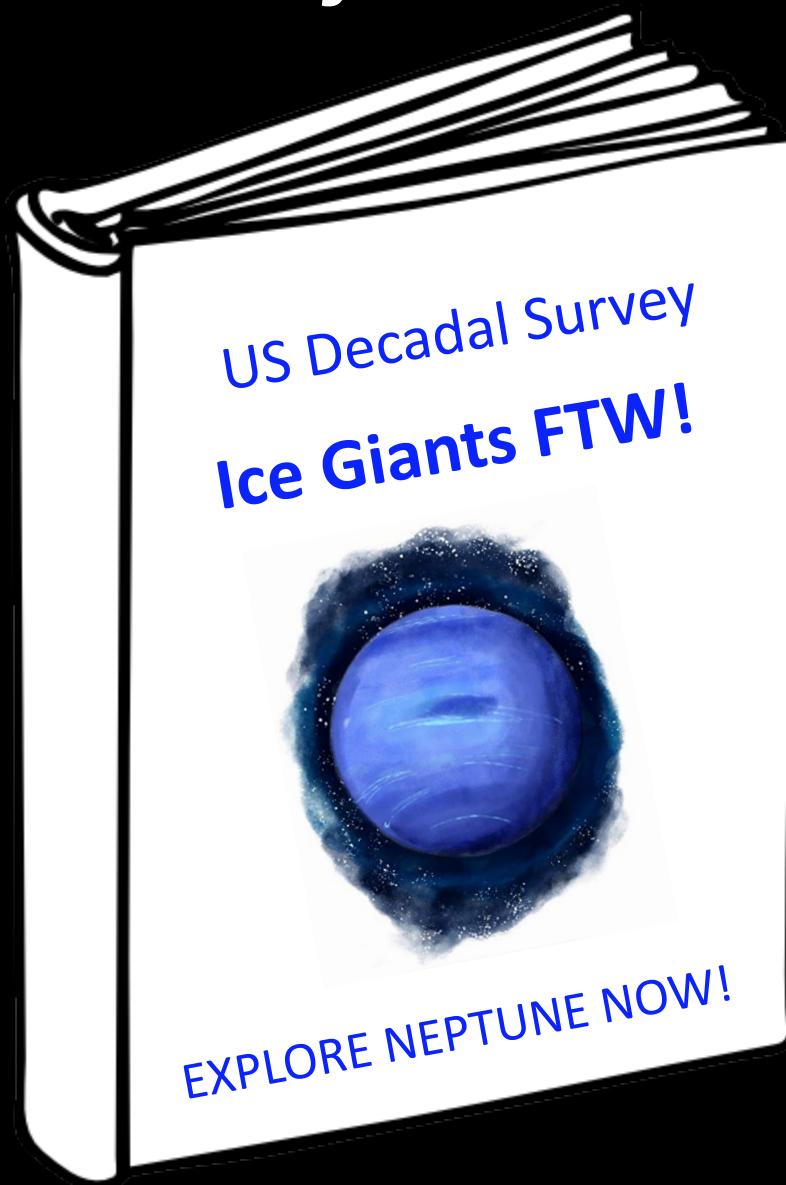
# Free advice for US planetary folks ...



Source: Pop Chart <https://popchart.co/products/the-chart-of-cosmic-exploration>

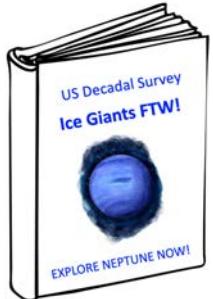


# What if we are wildly successful? What then?



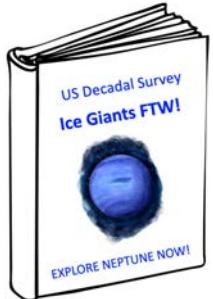
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NASA reads report and says: "Alrighty! Here's the money! Go Neptune!"



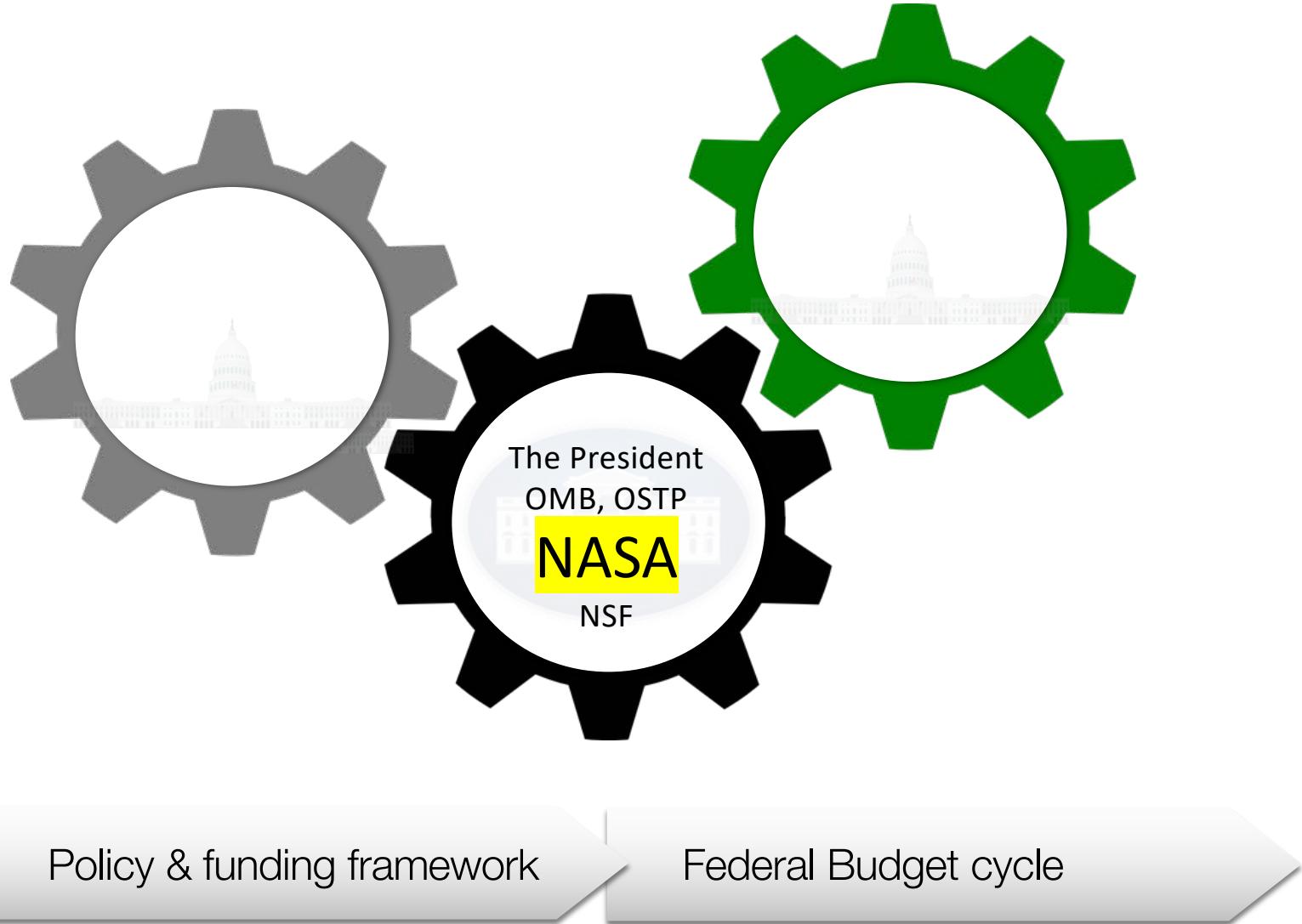
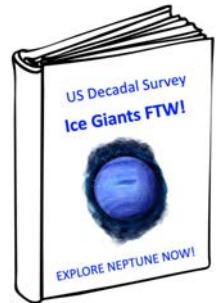


Policy & funding framework

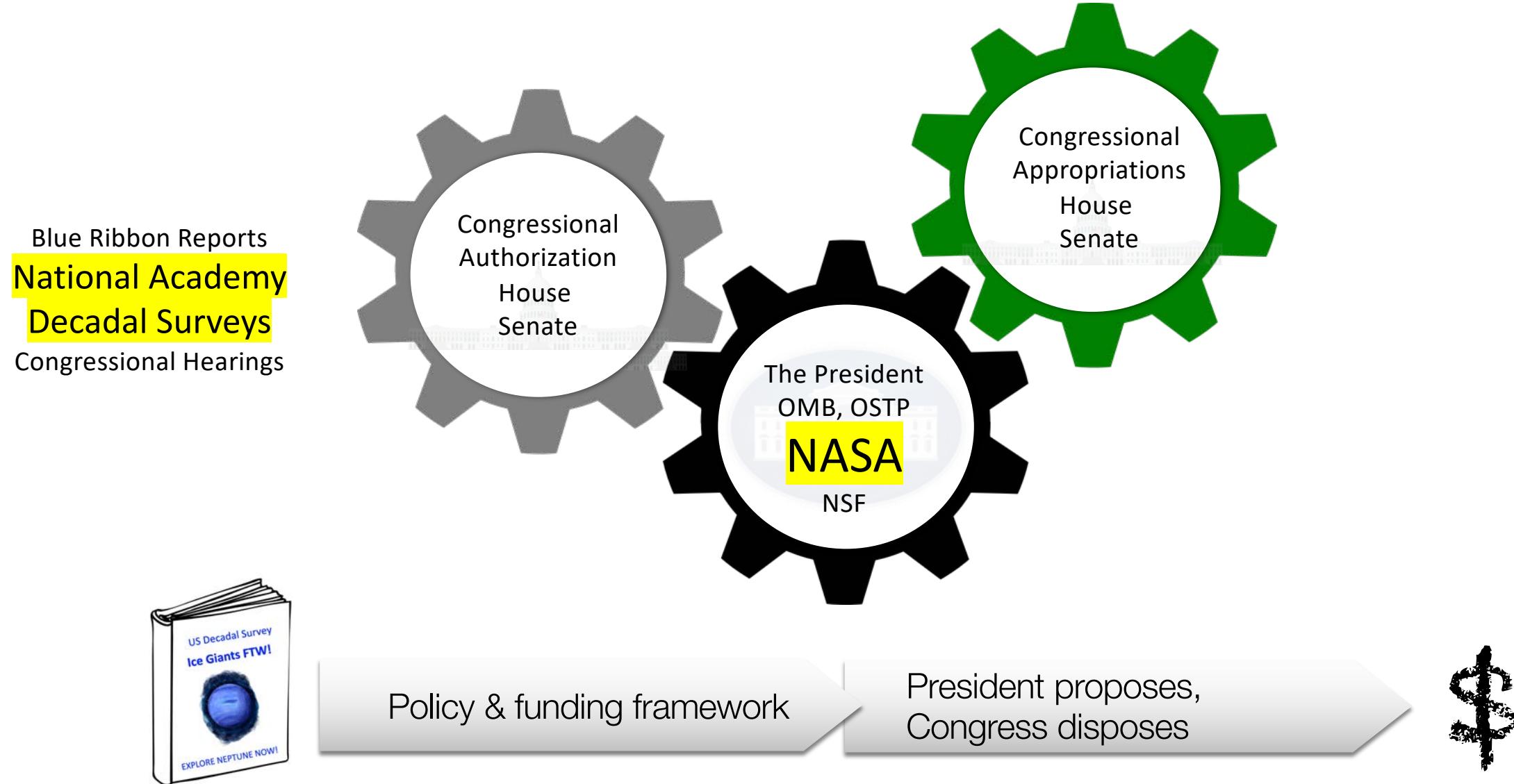
Federal Budget cycle



Blue Ribbon Reports  
**National Academy**  
Decadal Surveys  
Congressional Hearings

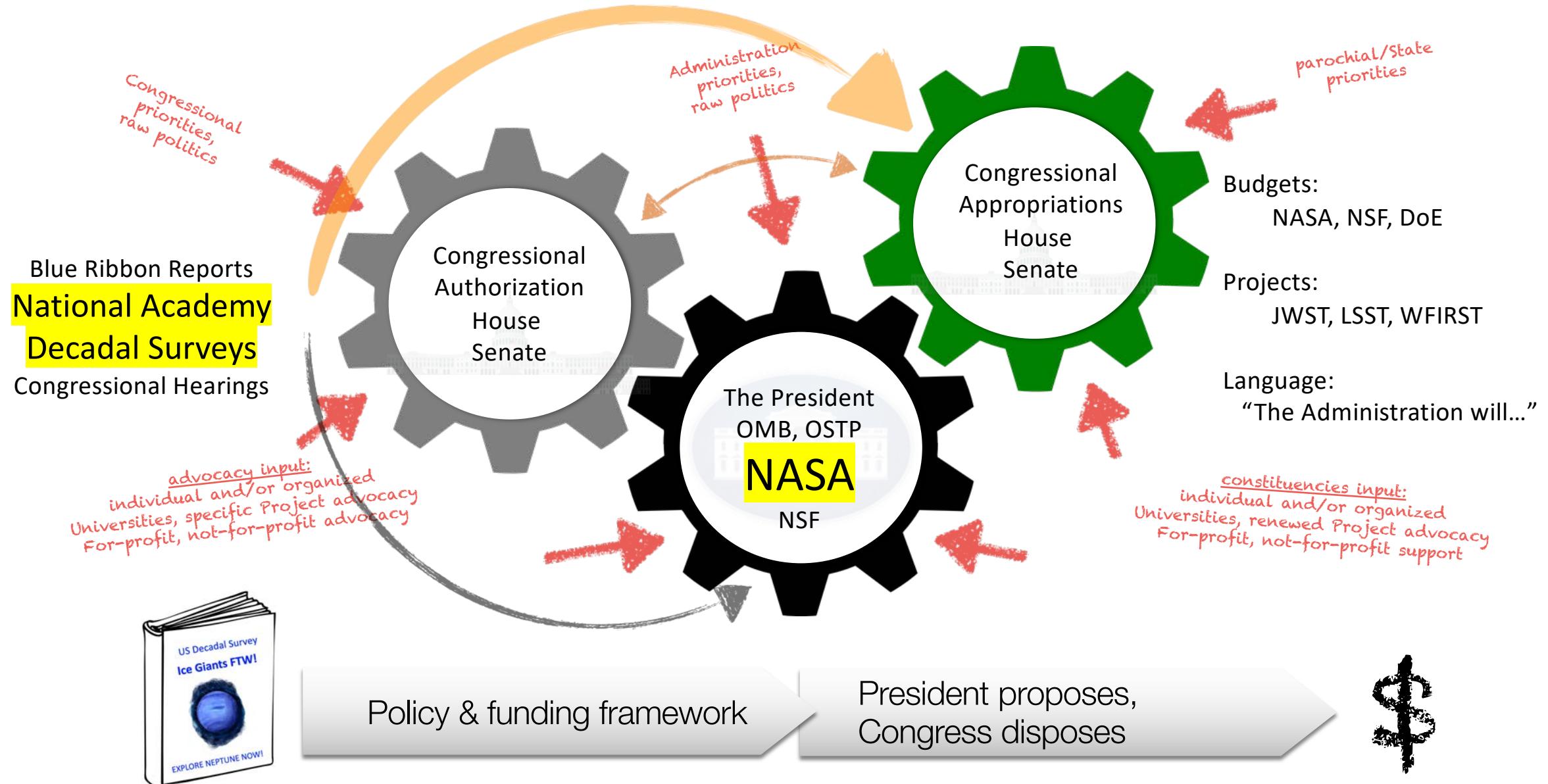


The US's founders purposely created a “Rube Goldberg like” system  
basic assumption: *no one constituency has a monopoly on wisdom*



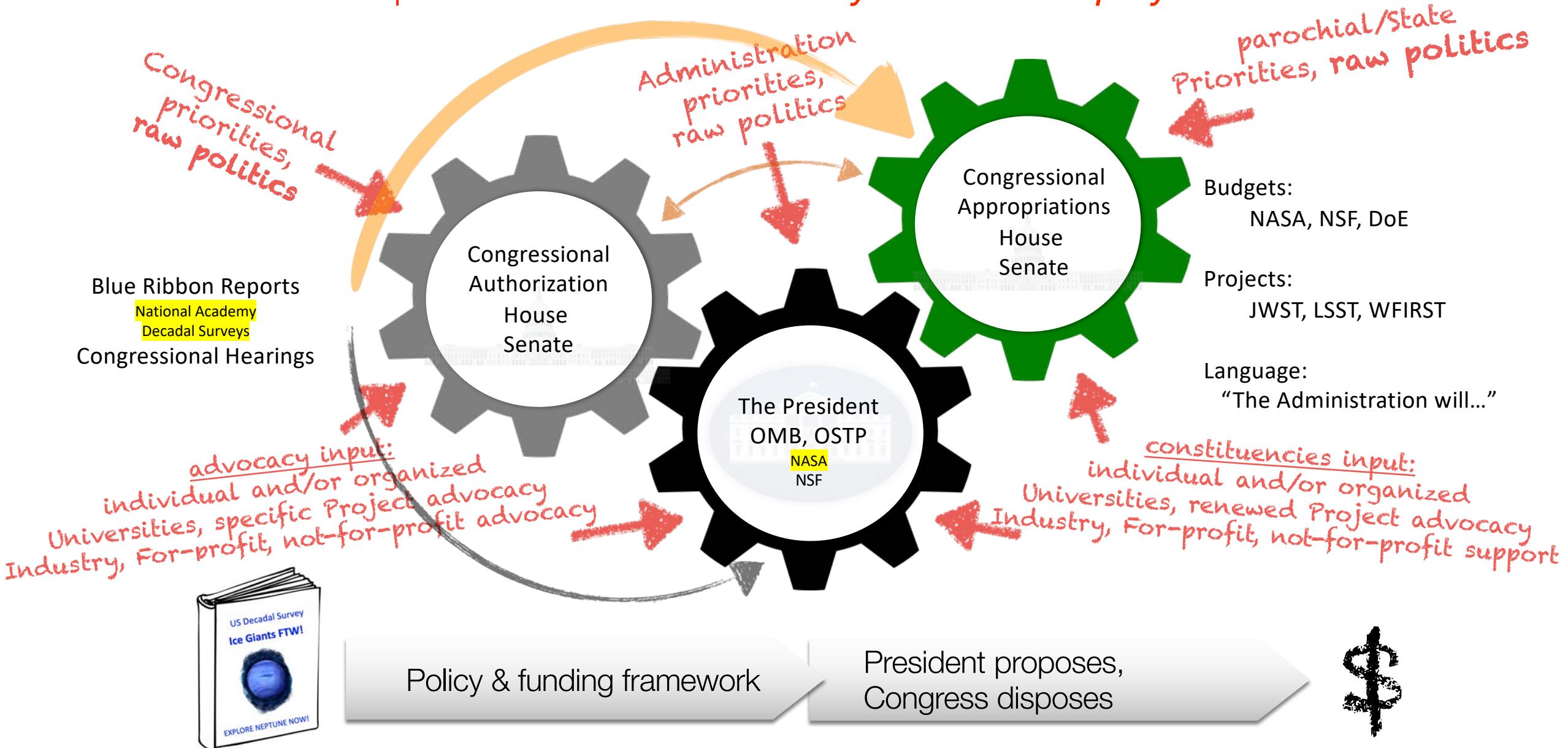
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# Planning within communities



rt Prof. Günther Hasinger Retweeted

Pedro Duque

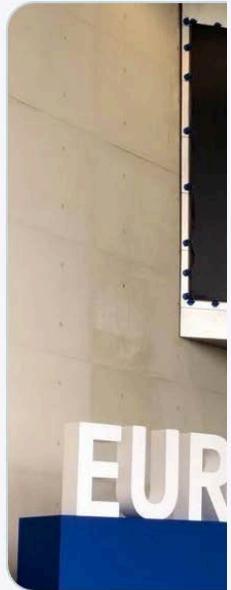
I'm delighted to this week for the decide on the p



Prof. Günther Hasinger @HasingerProf · Nov 28, 2019

The happy and proud @esascience team at the end of the very successful **nature**

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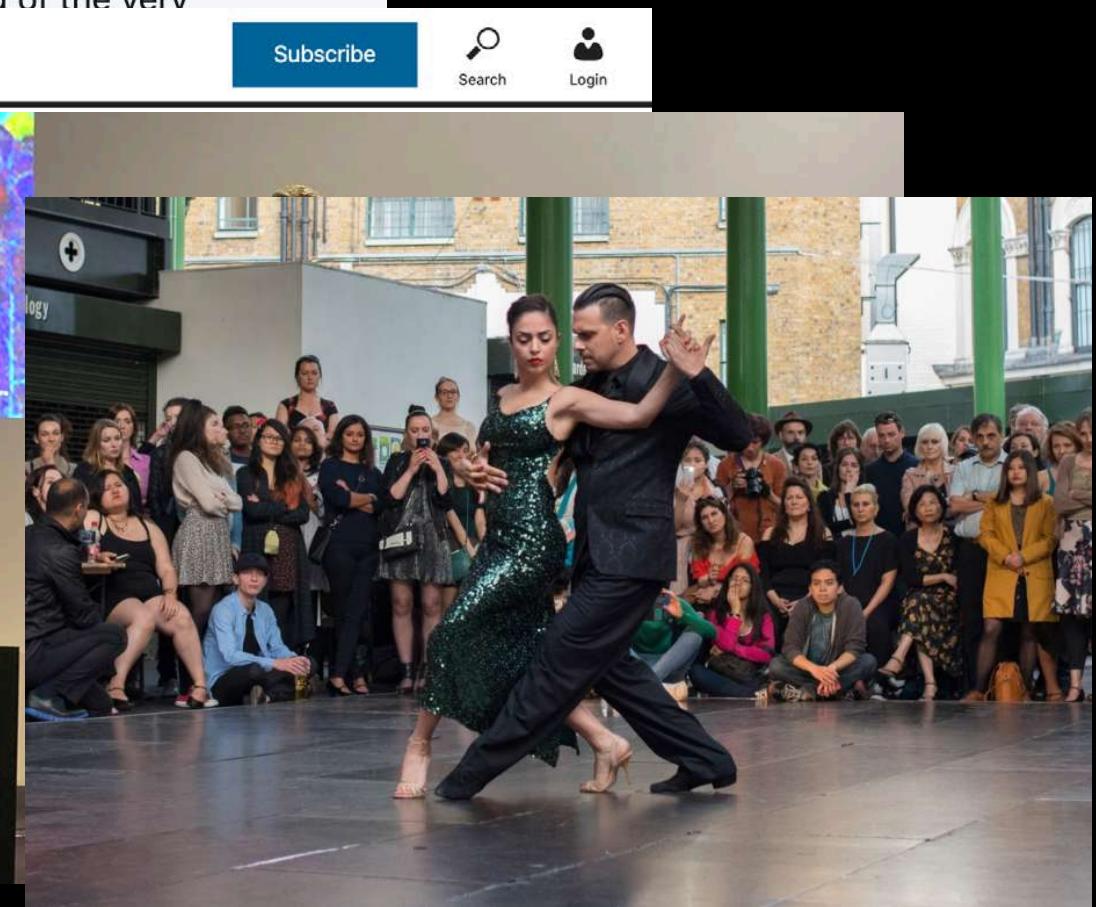
NEWS · 29 NOVEMBER 2019

## European science meets

Europe's space agency has a three-year budget deal

Elizabeth Gibney

The European space agency's pow-wow of European space agency's members compared with

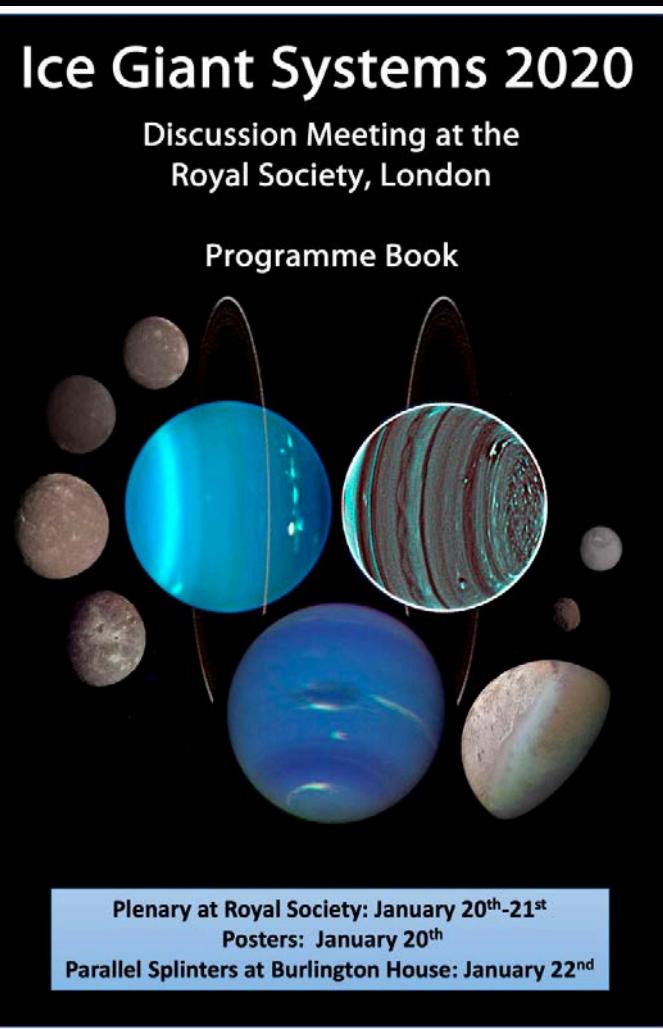




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# Synchronization across international borders



**Science:** Meetings like this!

Recent joint EPSC/DPS meeting in Geneva

European engagement in US decadals

**Politics:** Bilateral Agency talks

Multi-lateral Agency talks

NASA, ESA, JAXA, ISRO, KASI, others

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# Process



# Planning



# People



# People



It is *always* about the people

To build a cathedral

Empower the youth

Embrace your inner naïf

# To build a cathedral

## Bricklayer Perspectives

- Laying bricks
- Building a wall
- Building a cathedral

## Bricklaying Timescales

- Began in 1220
- Finished in 1472
- That's **252 years!**



York Minster

# Empower the youth

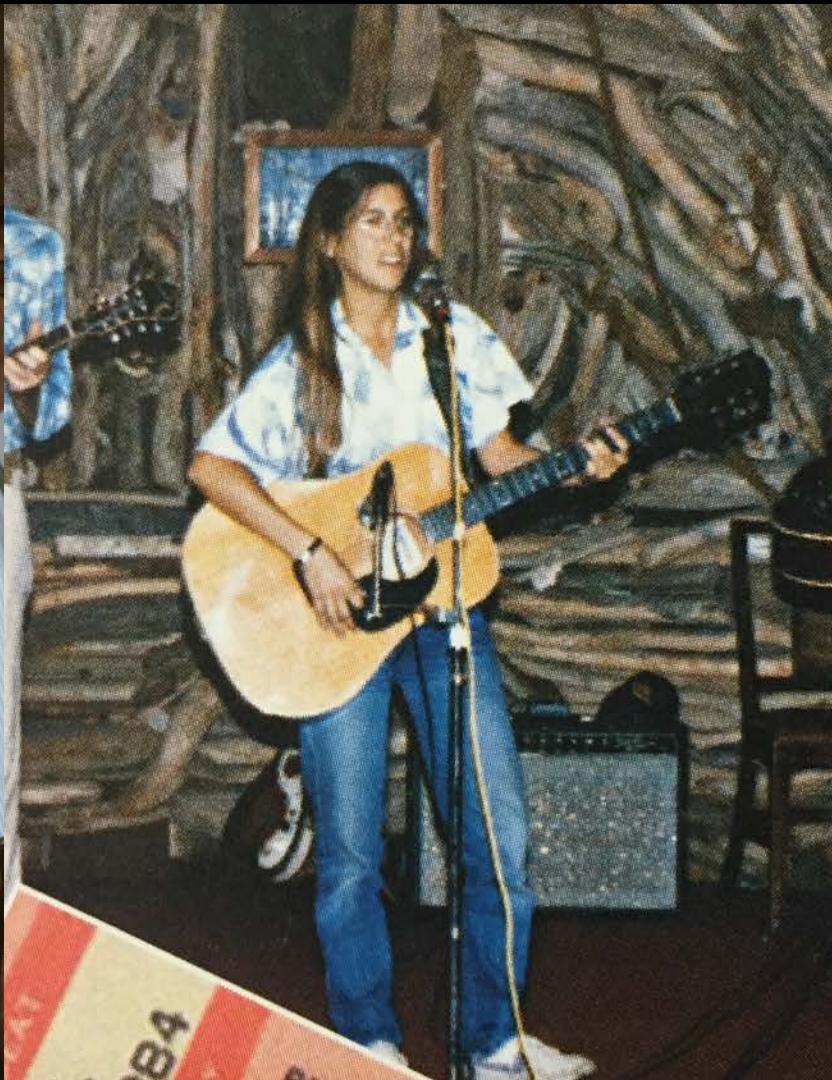
Audience participation moment!  
Everybody stand UP!

Born in 1960 or earlier? Sit down!

Born in 1990 or earlier? Sit down!



# Empower the youth



# Embrace your inner naïf

You don't know what you don't know

Prepare to be confounded and amazed

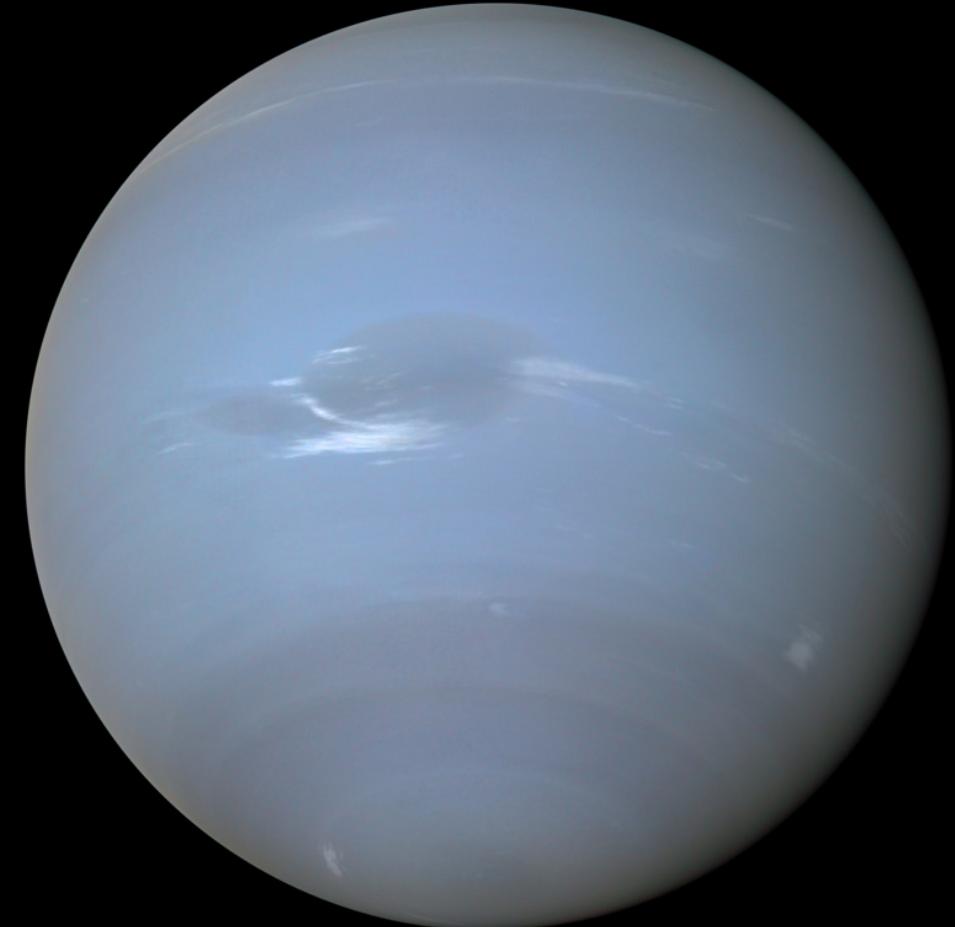
Get ready for feelings of joy,  
wonderment, pure unadulterated  
happiness

## Share those feelings WIDELY



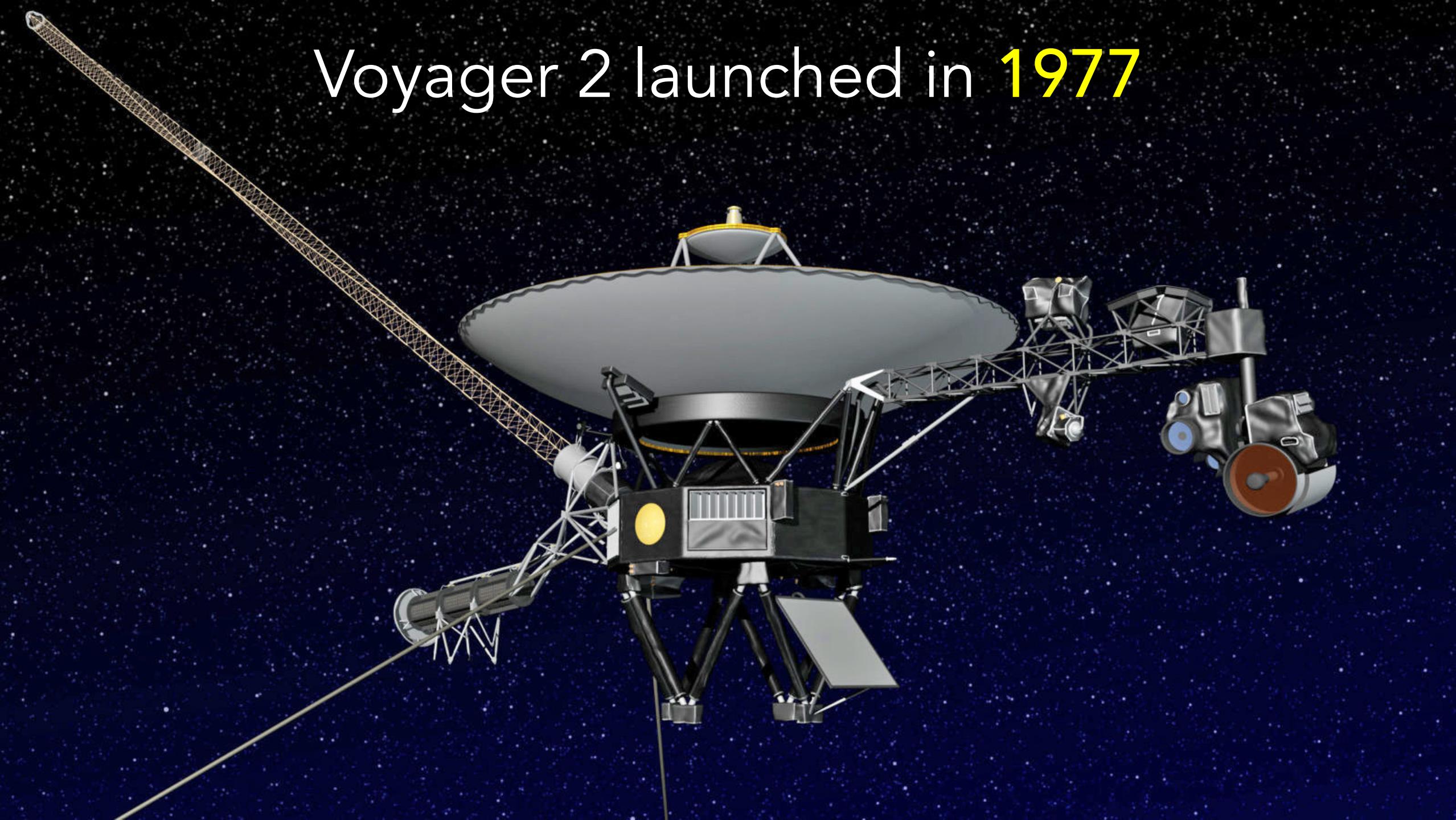
to wrap this up

# Why go to Uranus and Neptune **again**?



been there, done that

Voyager 2 launched in 1977



# What launched in 2019 (last year)?



1977: Apple II



1977: Atari VCS - CX2600

# What launched in 2019 (last year)?



	Apple II in 1977	iMac in 2019
Price:	US \$2638 with 48 K	US \$ 2,299 with 8 GB
CPU:	MOS 6502, 1.0 MHz	6-core 9th-generation Intel Core i5, up to 4.6 GHz
RAM:	4 K min, 48 K max	8 GB min, 64 GB max
Display:	12-inch, 6 colors (!)	27-inch with Retina 5K



Nintendo Switch Lite

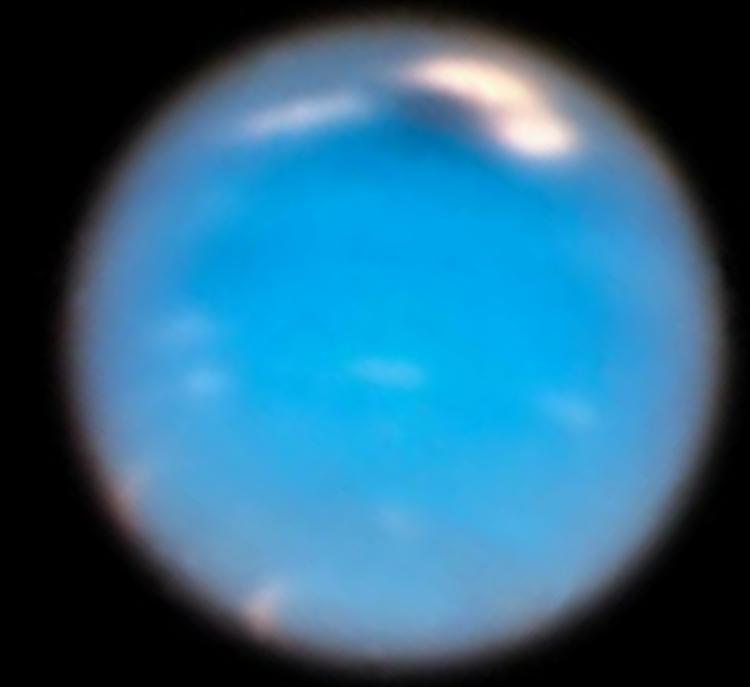
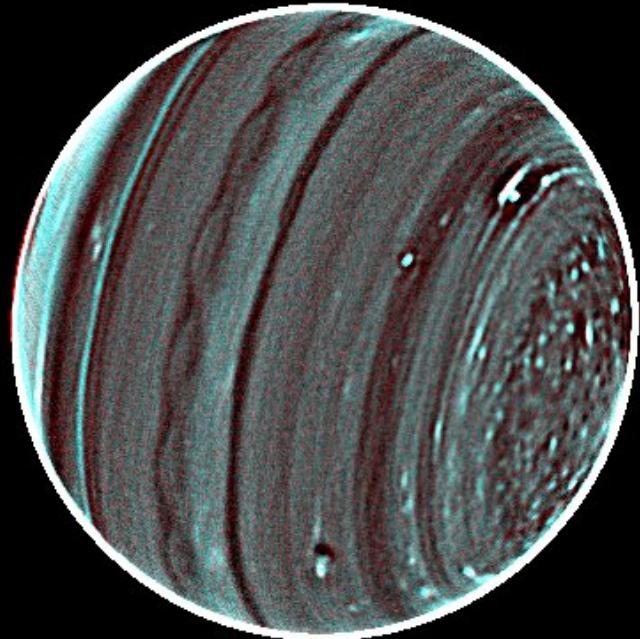
and also from 1977 to 1986 to 1989 to now  
these planetary systems have CHANGED

Ice giant cloud activity

Ring system structure

Satellite spectra

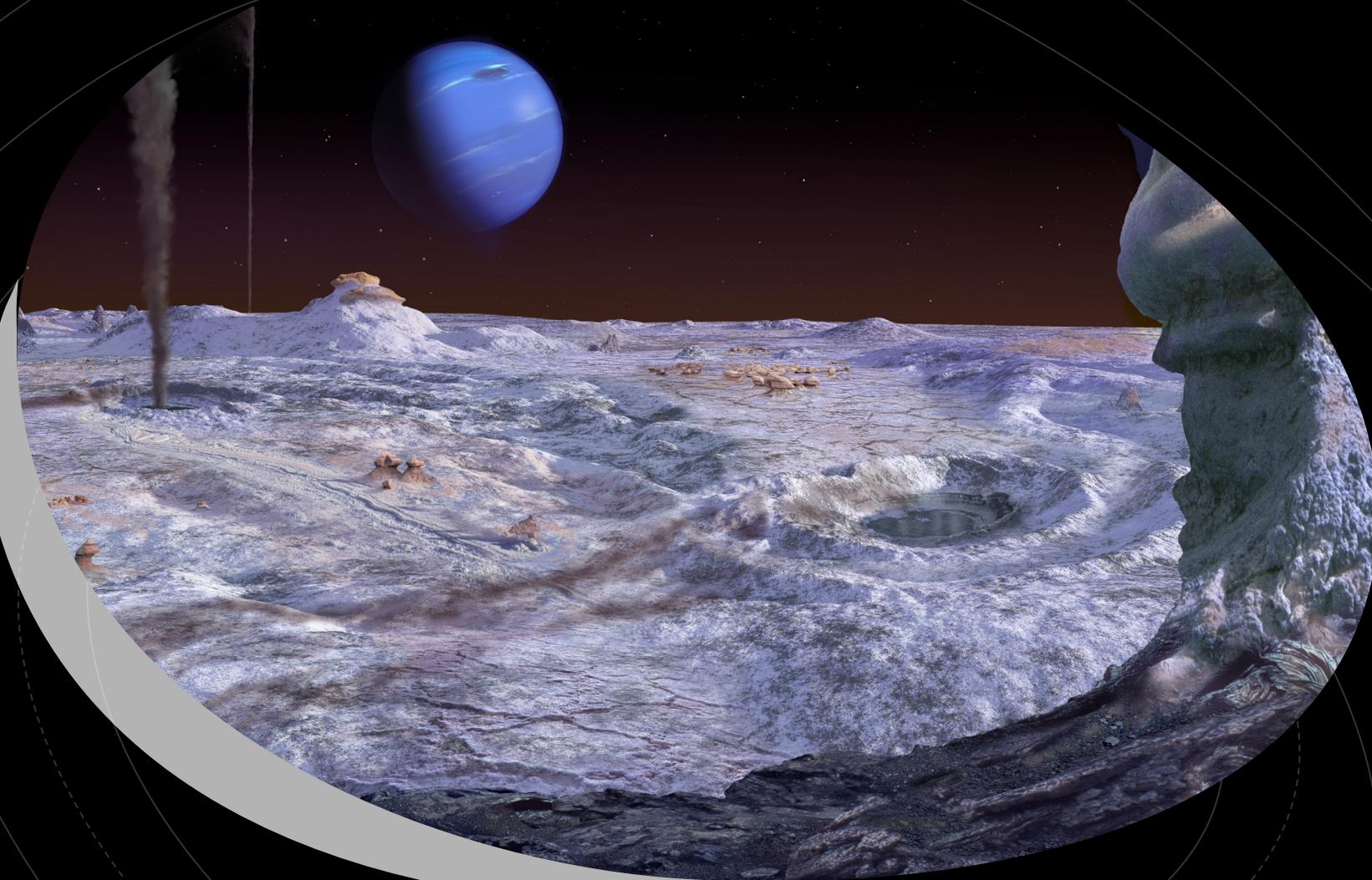
Probably magnetic fields



WE DON'T KNOW WHY – BEYOND THE REACH OF OUR TELESCOPES

one thing hasn't changed

we seek to explore



#UranusAndNeptuneLetsGoBack #ItsTime

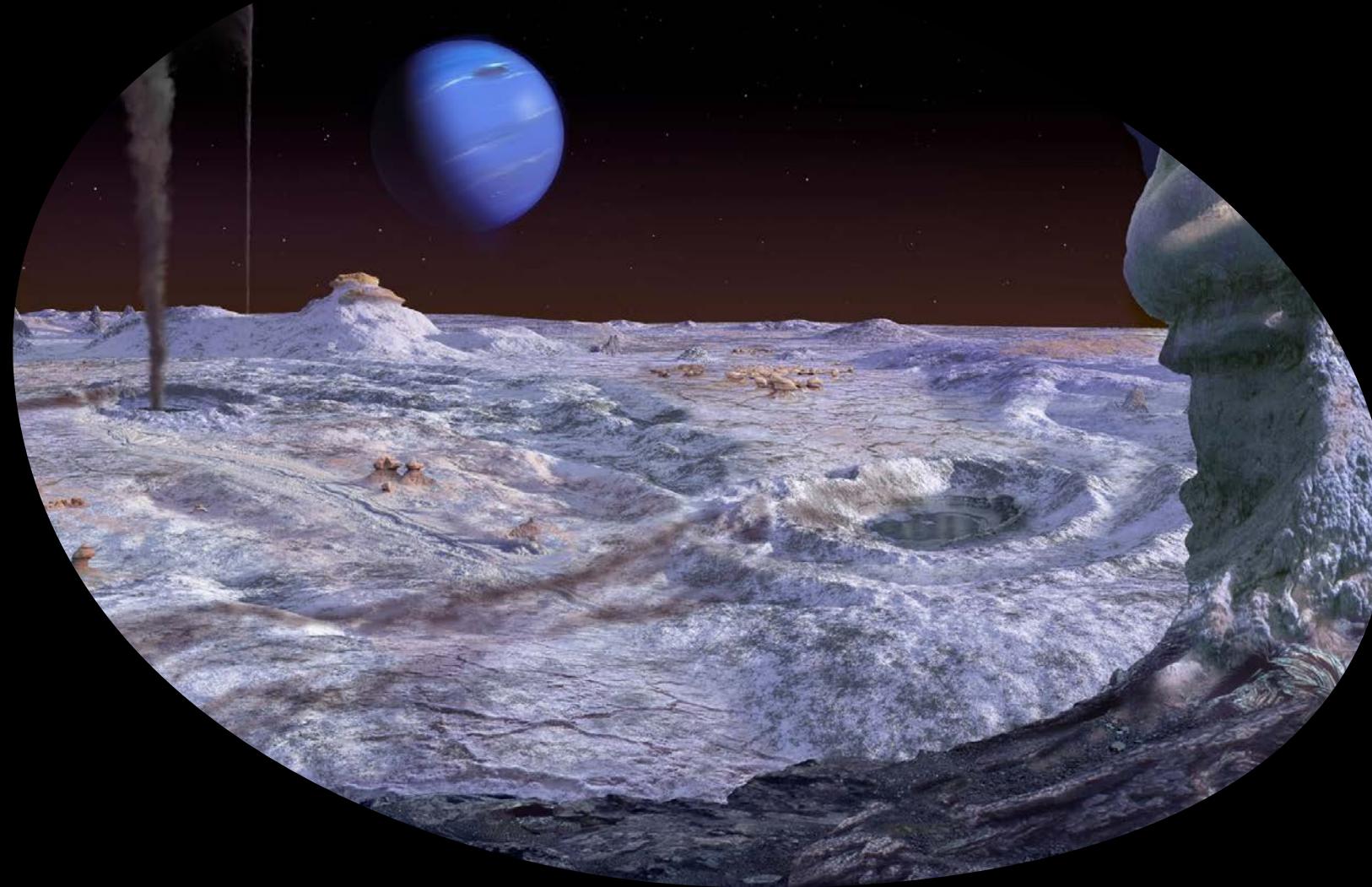
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