Getting Flight Missions to Flight

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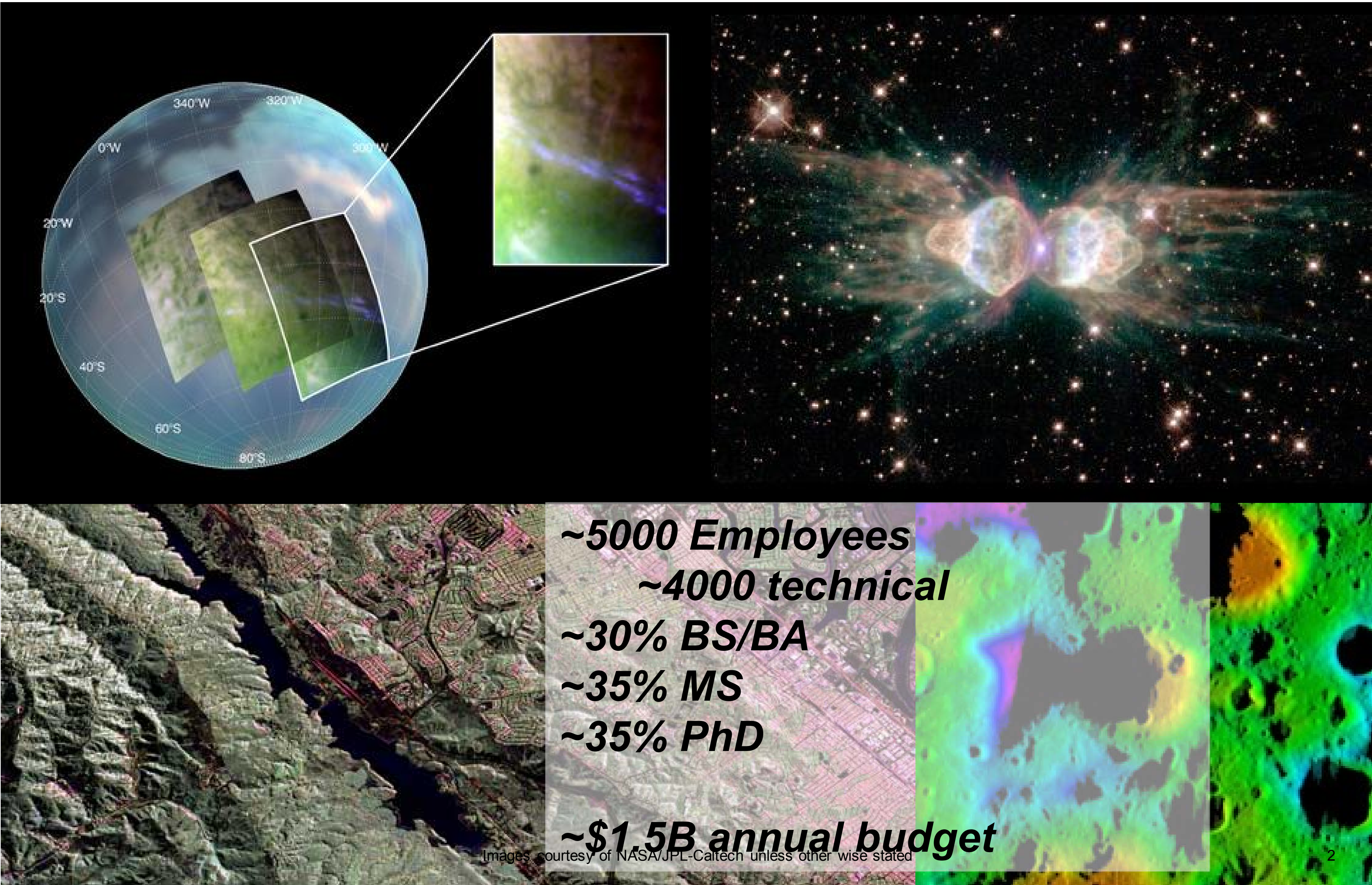
Bring the Universe to You



~5000 Employees
- ***~4000 technical***

~30% BS/BA
~35% MS
~35% PhD

~$1.5B annual budget

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Spacecraft and instruments across the solar system (and beyond)

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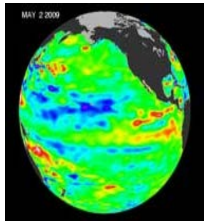
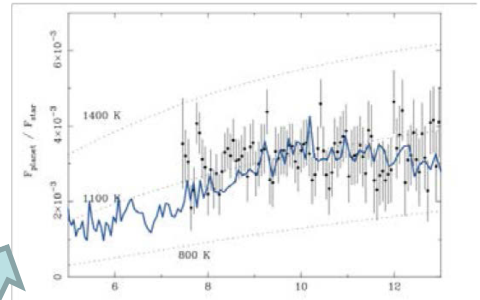
The Beginning of the Cycle





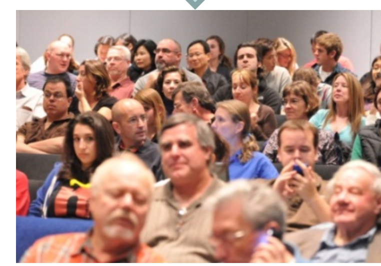
Scientific Research

New Measurement Idea

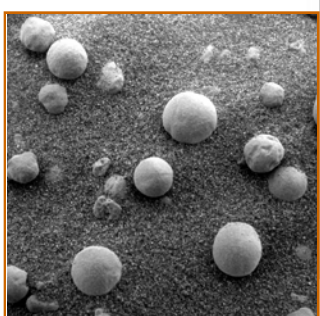


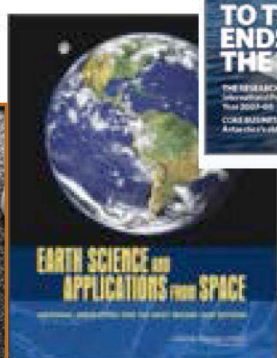
Enabling Technology

Community Endorsement



Science Observations Concepts





Mission Concept Formulation

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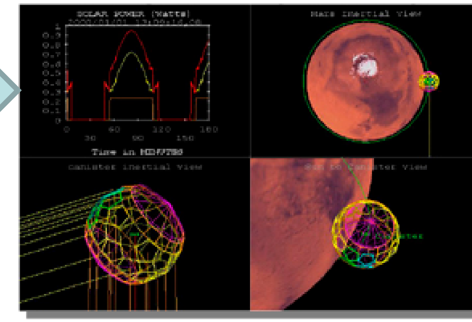
The Middle of the Life Cycle

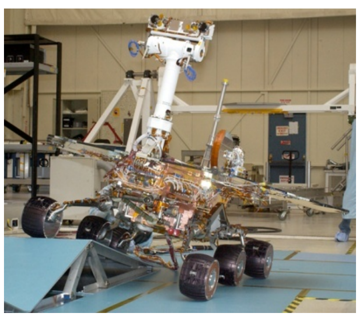
Mission Concept Formulation

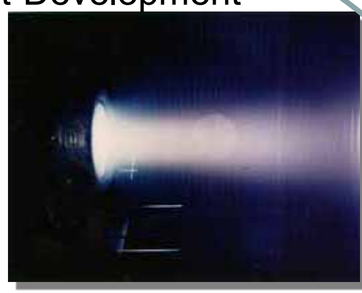
Proposals



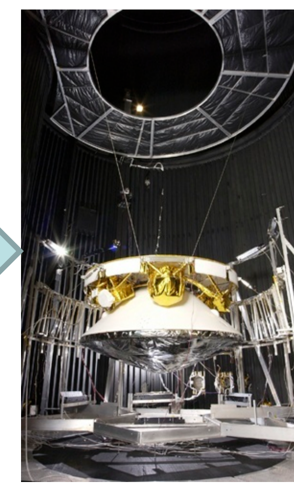
Mission Design

Spacecraft and
Instrument Development





Integration and Test



Environmental Test

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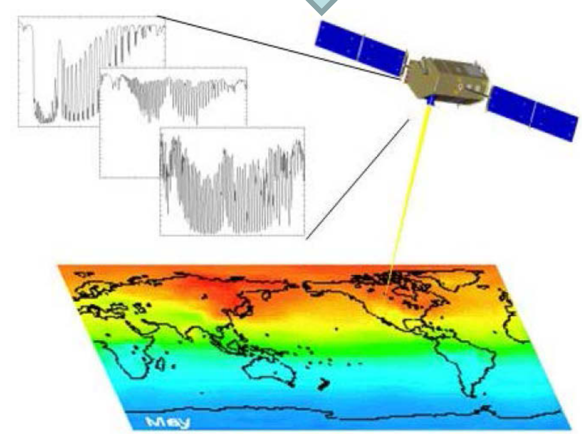
The End of the Life Cycle – or is it just the beginning?

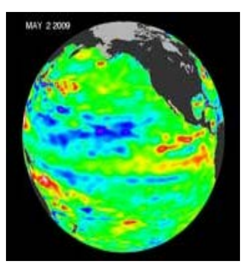
Environmental Test

Launch

Real Time Operations

Data Analysis & Science Return





Scientific Research

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Timing

- Alignment of community is crucial
  - Assessment groups and Space Studies Board
  - Presidential and Congressional Science Advisor
- Acceptance of proposals
  - Congressional leanings
  - Budgets - overruns of other missions
- Proposals are often submitted more than once
  - Once accepted – need to be continually re-sold

Getting the go-ahead for a mission often takes longer than actually building and launching it

Tracing Mission to Science

Science Goals	Science Objectives	Scientific Measurement Requirements: Observables	Scientific Measurement Requirements: Physical parameters	Instrument Functional Requirements		Projected Performance	Mission Functional Requirements (Top Level)
Goal 1	Objective 1	Absorption line	Column density of absorber	Alt. Range	XX km	ZZ km	Observing strategies: requires yaw and elevation maneuvers
Goal 2		Emission line	Density and temperature of emitter				Launch window: to meet nadir and limb overlap requirement. Window applies day to day
Etc.			Size of features	Vert. Resol.	XX km	ZZ km	Need AA seasons to trace evolution of phenomena
		Morphological feature		Horiz. Resol.	XX deg x XX lat x XX long	ZZ deg x ZZ lat x ZZ long	
			Rise time of eruptive phenomenon	Temp. Resol.	XX min	ZZ min.	Need AA months of observation to observe variability of phenomena
				Precision	XX K	ZZ K	
		Rate of change of observable phenomenon		Accuracy	XX K	ZZ K	
	Objective 2 to N			Repeat above categories			

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Europa Goal, Objectives, Investigations

Goal	Science Objective	Science Investigation
Explore Europa and investigate its habitability.	**A. Ocean** — **Characterize the ocean and deeper interior.**	A1. Determine the amplitude and phase of the gravitational tides.
		A2. Determine the induction response from the ocean over multiple frequencies.
		A3. Characterize surface motion over the tidal cycle.
		A4. Determine the satellite's dynamical rotation state.
		A5. Investigate the core and rocky mantle.
	B. Ice — **Characterize the ice shell and any subsurface water, and the nature of surface-ice-ocean exchange.**	B1. Characterize the distribution of any shallow subsurface water.
		B2. Search for an ice-ocean interface.
		B3. Correlate surface features and subsurface structure to investigate processes governing communication among the surface, ice shell, and ocean.
	C. Chemistry — **Determine global surface compositions and chemistry, especially as related to habitability.**	C1. Characterize surface organic and inorganic chemistry, including abundances and distributions of materials, with emphasis on indicators of habitability.
		C2. Relate compositions to geological processes, especially communication with the interior.
		C3. Assess the effects of radiation on surface composition, albedo, sputtering, and redox chemistry.
		C4. Characterize the nature of exogenic materials.
	D. Geology — **Understand the formation of surface features, including sites of recent or current activity, and identify and characterize candidate sites for future *in situ* exploration.**	D1. Characterize magmatic, tectonic, and impact features.
		D2. Search for areas of recent or current geological activity.
		D3. Investigate global and local heat flow.
		D4. Assess relative surface ages.
		D5. Characterize the physical properties of the regolith, and assess processes of erosion and deposition.
	E. External — **Characterize the magnetic environment and moon-particle interactions.**	E1. Characterize the magnetic environment.
		E2. Characterize the ionosphere and neutral atmosphere and their dynamics, with implications for surface interactions.
		E3. Characterize relationships between the magnetic field and plasma.
		E4. Characterize the global radiation environment.
	F. Neighbors — **Determine how the components of the Jovian system operate and interact, leading to potentially habitable environments in icy moons.**	F1. Determine the nature and history of the geological activity and interior evolution of the Galilean satellites.
		F2. Understand the processes that determine the composition, structure and dynamics of the Jovian atmosphere as a type example of a gas giant planet.
		F3. Study the interactions between Jupiter's magnetosphere and its satellites.

Europa Explorer Themes:

Origins	Evolutio	Processe	Habitabilit	Life

Links between Investigations and Instruments: *Europa Science*

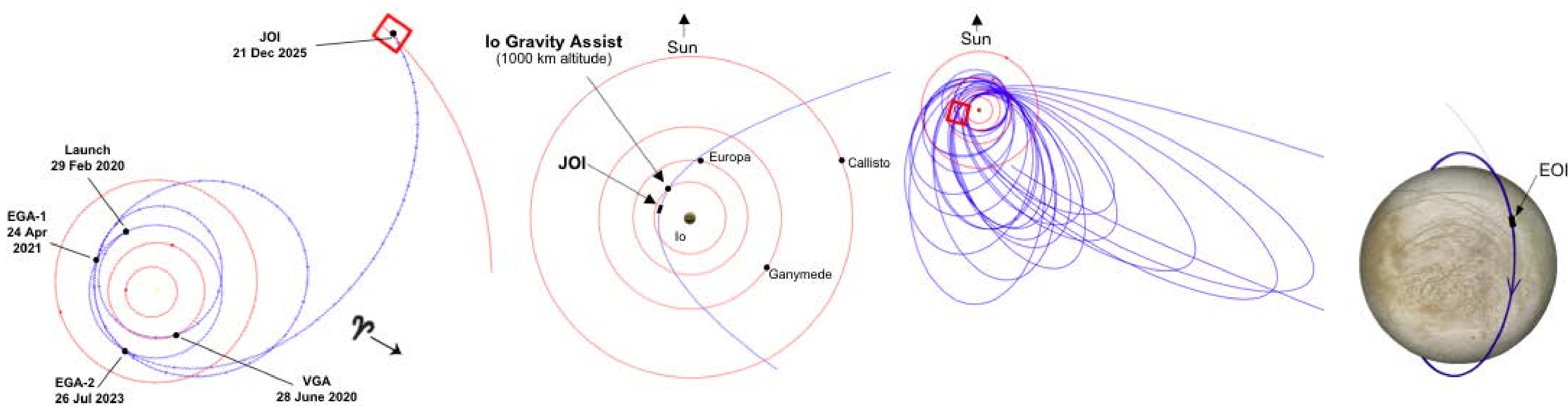
Example

Objective		Science Investigation	RS	LA	IPR	VIRIS	UVS	INMS	WAC +MAC	NAC	TI	MAG	PPI
A. OCEAN: Characterize the extent of the ocean and its relationship to the deeper interior.	A1.	Determine the amplitude and phase of the gravitational tides.	P	S									
	A2.	Characterize the magnetic environment (including plasma), to determine the induction response from the ocean, over multiple frequencies.										P	S
	A3.	Characterize surface motion over the tidal cycle.	S	P									
	A4.	Determine the satellite's dynamical rotation state.	P	S									
	A5.	Investigate the core, rocky mantle, and rock-ocean interface.	P	P								S	S
B. ICE: Characterize the ice shell and any subsurface water, including heterogeneity, and the nature of surface-ice-ocean exchange.	B1.	Characterize the distribution of any shallow subsurface water.		S	P				S				
	B2.	Search for an ice-ocean interface.		S	P				S				
	B3.	Correlate surface features and subsurface structure to investigate processes governing material exchange among the surface, ice shell, and ocean.	S	P	P	P	S		P	S	P		
	B4.	Characterize regional and global heat flow variations.			P						S		
C. CHEMISTRY: Determine global surface compositions and chemistry, especially as related to habitability.	C1.	Characterize surface organic and inorganic chemistry, including abundances and distributions of materials, with emphasis on indicators of habitability and potential biosignatures.				P	S	P					
	C2.	Relate compositions to geological processes, especially material exchange with the interior.		S	P	P	P		P	S	S		
	C3.	Characterize the global radiation environment and the effects of radiation on surface composition, atmospheric composition, albedo, sputtering, sublimation, and redox chemistry.				P	P	P		S	S		S
	C4.	Characterize the nature of exogenic materials.				P	S	P	S				P
D. GEOLOGY: Understand the formation of surface features, including sites of recent or current activity, and identify and characterize candidate sites for future *in situ* exploration.	D1.	Determine the formation history and three-dimensional characteristics of magmatic, tectonic, and impact landforms.		P	P	S	S		P	S	S		
	D2.	Determine sites of most recent geological activity, and evaluate future landing sites.				S	P		P	S	P		S
	D3.	Investigate processes of erosion and deposition and their effects on the physical properties of the surface debris.				S				P	P	S	S

JEO science investigations are well addressed by the model payload, and instruments are Primary (P) or Secondary (S) in addressing multiple investigations

Europa Mission Design: Example

- Interplanetary trajectories feature gravity assists to greatly reduce the required specific energy of launch
- Jupiter Orbit Insertion occurs low in Jupiter's gravity well, significantly reducing ΔV
- Gravity-assist tour of Jovian satellites greatly reduces size of Europa Orbit Insertion maneuver



Europa Science Value: Example

	Objective	Investigation	Instrument	Jupiter System Science	1 Global Framewrk		2 Regional Proc.		3 Targ. Proc.
					1A	1B	2A	2B	
B. Ice	Characterize the ice shell and any subsurface water, including their heterogeneity, and the nature of surface-ice-ocean exchange.	B1 Characterize the distribution of any shallow subsurface water.	B1a Radar sounder (nominally ~50 MHz, with ~10 MHz bandwidth)		3	3	4	4	5
			B1b Wide angle camera (stereo) and laser altimeter		1	2	3	4	4
		B2 Search for an ice-ocean interface.	B2a Radar sounder (nominally ~5 or 50 MHz, with ~1 MHz bandwidth)		1	2	2	3	4
			B2b Wide angle camera (stereo) and laser altimeter		1	2	3	4	4
		B3 Correlate surface features and subsurface structure to investigate processes governing material exchange among the surface, ice shell, and ocean.	B3a Radar sounder (dual frequency, nominally ~5 & ~50 MHz, with ~1 and ~10 MHz bandwidth)		3	3	4	4	5

5	Definitely addresses full science investigation.
4	May address full science investigation.
3	Definitely addresses partial science investigation.
2	May address partial investigation.
1	Touches on science investigation.
0	Does not address science investigation.

Science objectives are mapped to mission design phases

Looking back …

- Identify your critics and work to make them part of the team
- Small science community – factions can rally together or split the community apart
- Shifting priorities at NASA made advocacy increasingly important
- Importance of precursor science – learn what was essential for previous instrument/mission design
- Invest in enabling technology
- International partnerships essential to mature technology and acquire credibility
- Persistence is the key to successful investigations. They are successful only after the data analysis is complete, and funding for science is always at risk and frequently cut
- Make it fun along the way – celebrate your successes

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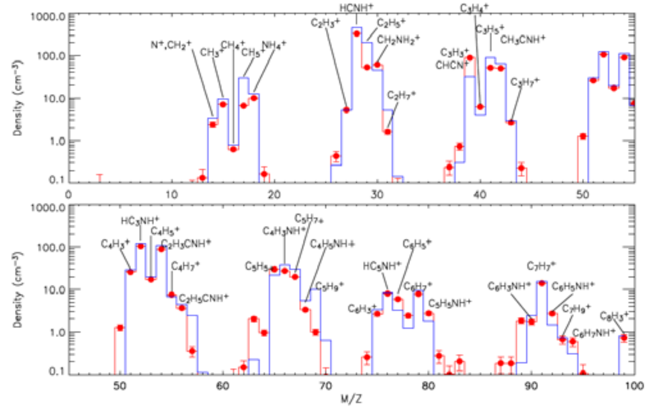
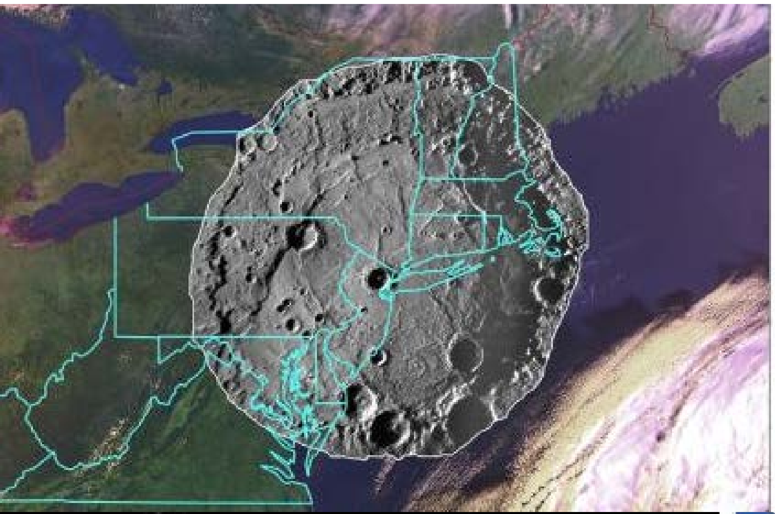
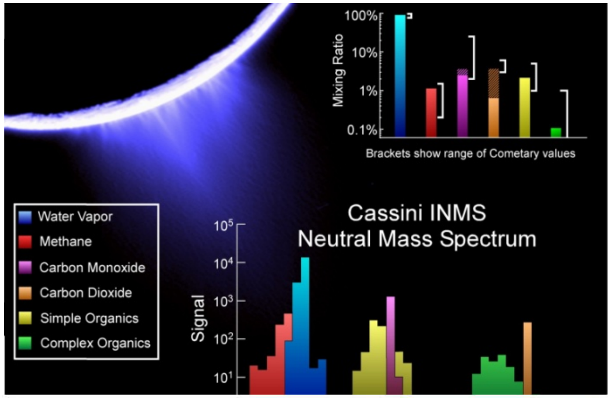
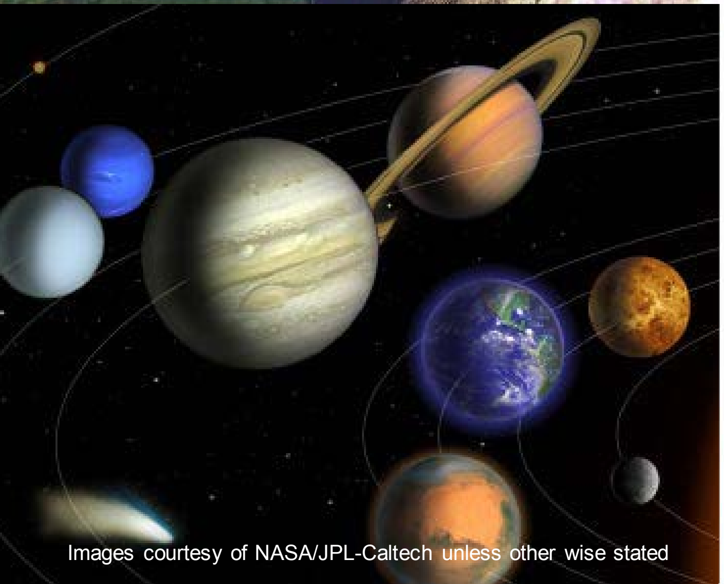
Why Do I Do This?

- Science knowledge









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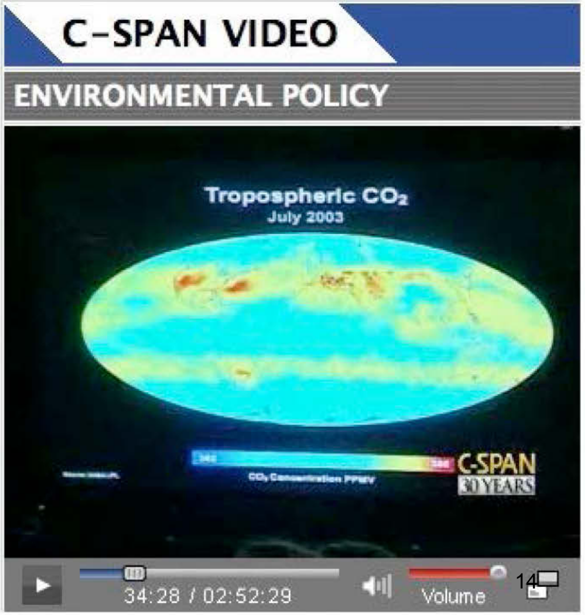
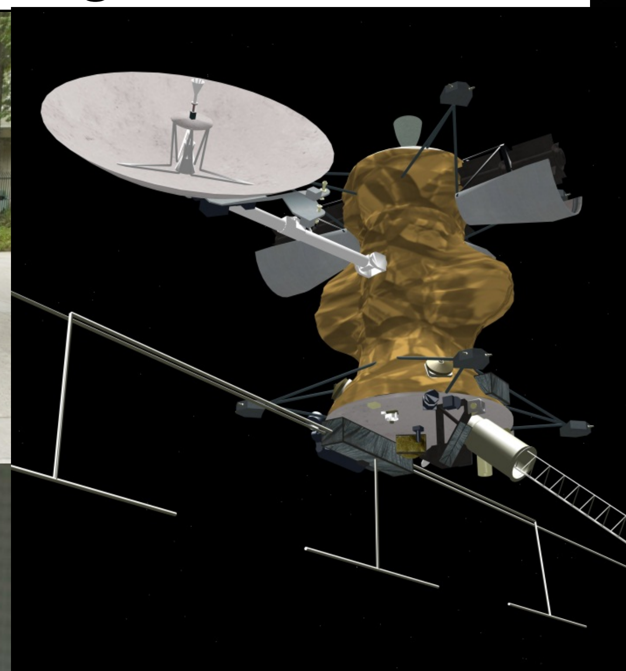
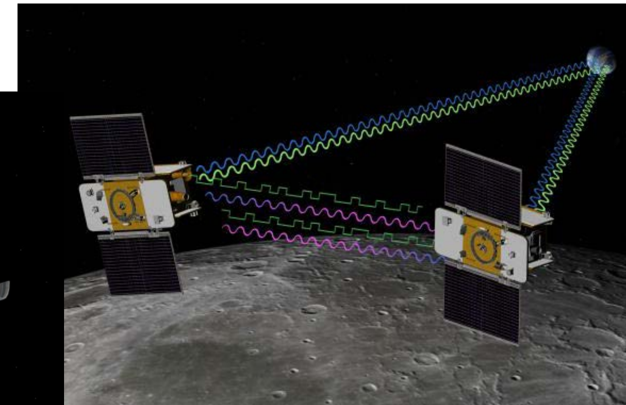
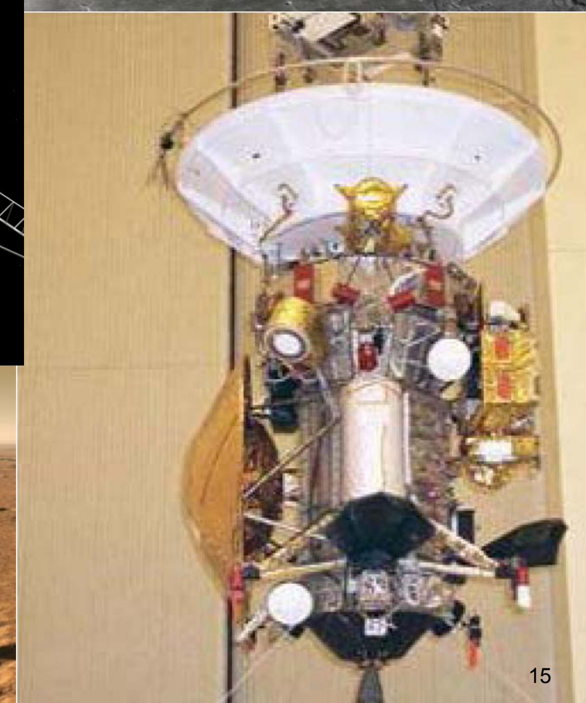


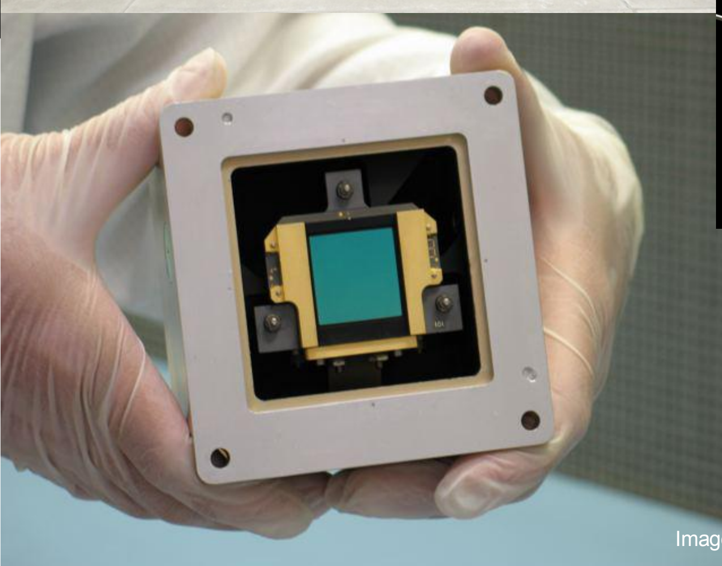
Why Do I Do This?

- Science knowledge
- Engineering challenge









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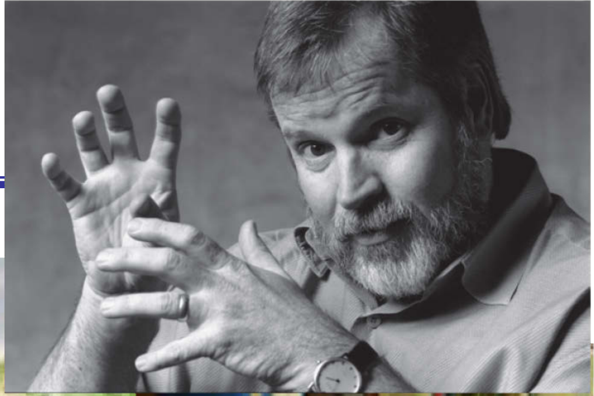
Why Do I Do This?



- Science knowledge
- Engineering challen
- People

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It's Worth It

- Timelines can be months to decades
- The challenges are continuous
  - Technical
  - Scientific support
  - Congressional support
- In the end, it comes down to the people you work with
  - Premier scientists, engineers, managers, technicians and business people

A passion to learn unites us all