National Aeronautics and Space Administration

# NASA/JPL Space Missions – A Quest for Learning

## Luncheon Keynote Talk

**Custom Integrated Circuits Conference (CICC) 2012**

**11 September 2012**
**Santa Clara, California**


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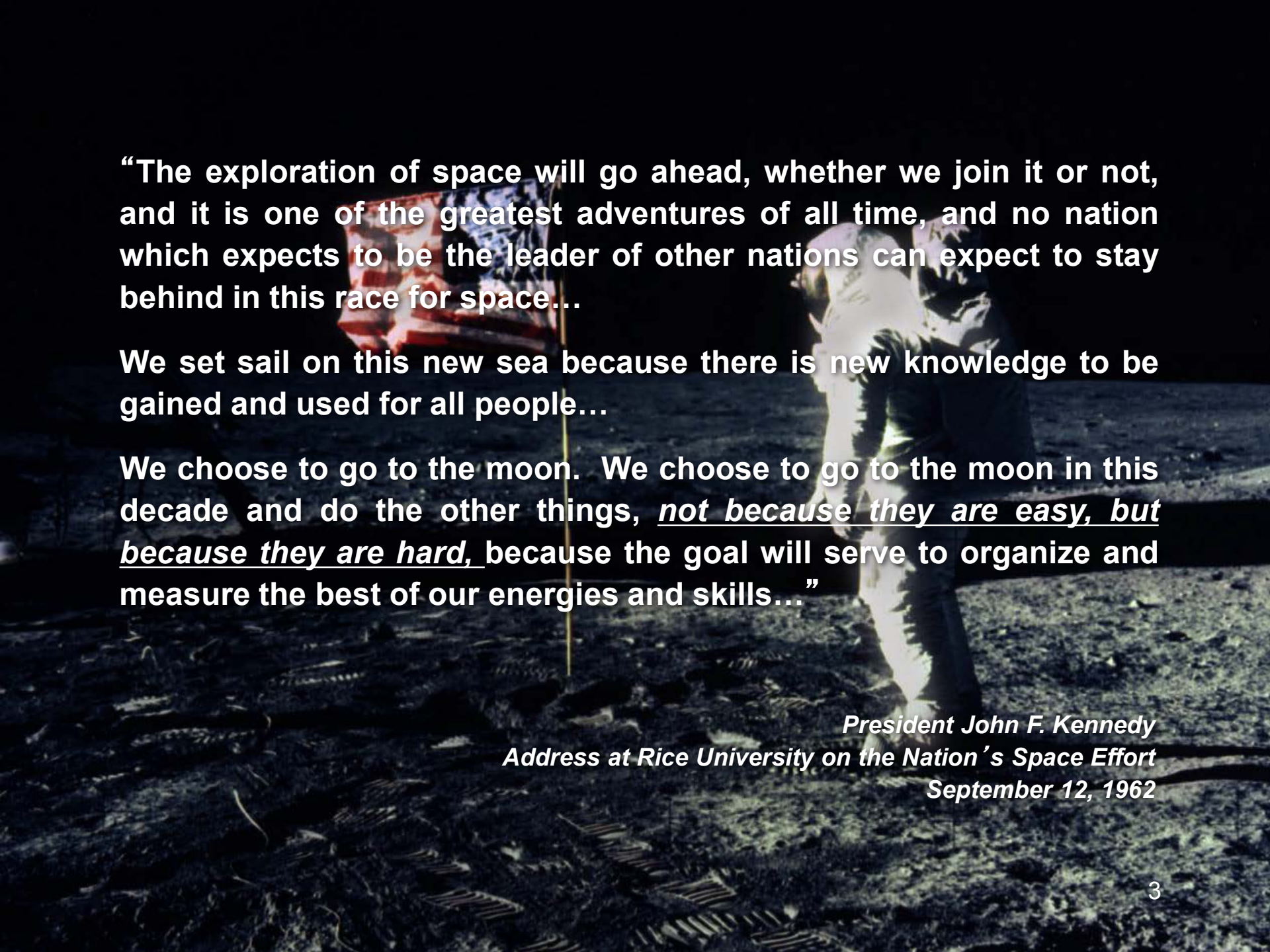
**Mars Science Laboratory (Curiosity rover)**
Launched: Nov. 26, 2011
Landed : Aug. 5, 2012

www.nasa.gov

# MSL Landing

- **Some Thoughts about MSL**
  - JPL Director Charles Elachi looking up at Mars before the MSL landing: ***You are going to have a visitor … And the planet smiled.***
  - MSL Landing team leader, Adam Stelzner: ***Engineers, we are kind of tool makers, pioneers, and that's reflected in the results of tonight.***
  - NASA Administrator Charles Bolden: ***As incredible as our achievement was tonight, we just succeeded one more time in raising the bar even higher.***
  - President Barack Obama : ***Curiosity is an unprecedented feat of technology that will stand as a point of national pride far into the future. It proves that even the longest of odds are no match for our unique blend of ingenuity and determination … If in fact you do make contact with Martians please let me know right away, I have a lot of other things on my plate, but that that will go to the top of the list even if they're just microbes.***



**"The exploration of space will go ahead, whether we join it or not, and it is one of the greatest adventures of all time, and no nation which expects to be the leader of other nations can expect to stay behind in this race for space…**

**We set sail on this new sea because there is new knowledge to be gained and used for all people…**

**We choose to go to the moon. We choose to go to the moon in this decade and do the other things, *not because they are easy, but because they are hard,* because the goal will serve to organize and measure the best of our energies and skills…"**

***President John F. Kennedy***
***Address at Rice University on the Nation's Space Effort***
***September 12, 1962***

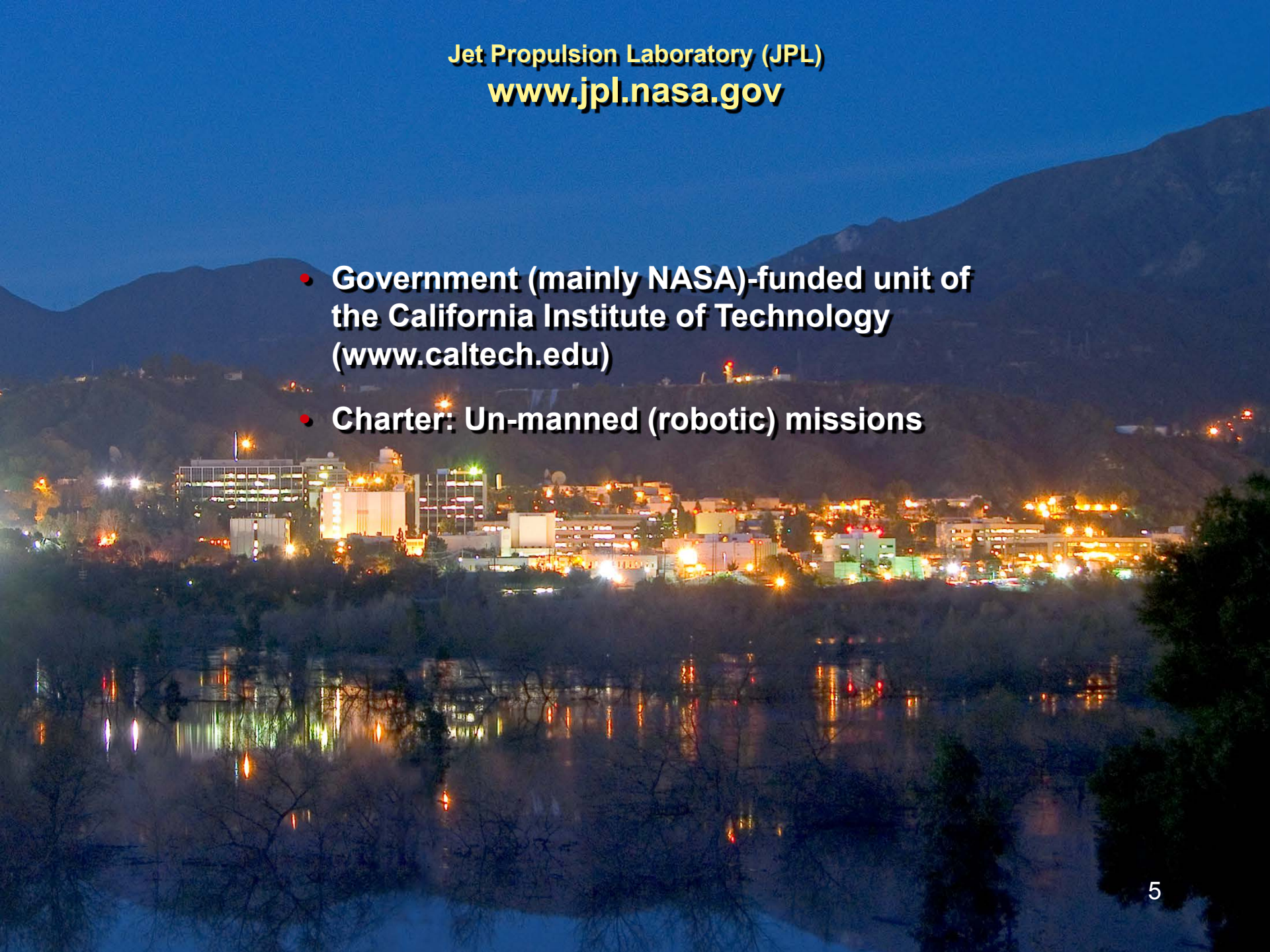
# NASA

## 50+ years of exploration and discovery

## 1958 – 2012

### NASA Centers

- ARC
- DFRC
- GRC
- GSFC
- HQ
- JPL
- JSC
- KSC
- LaRC
- MSFC
- SSC

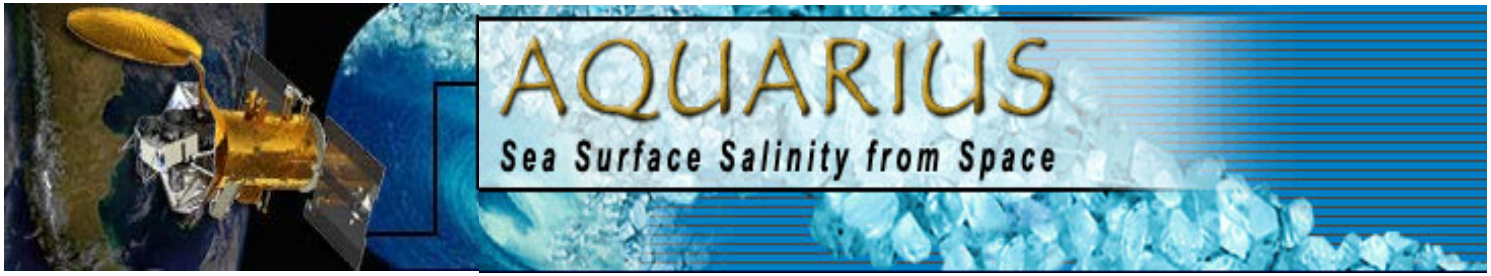


## Jet Propulsion Laboratory (JPL)
## www.jpl.nasa.gov

- Government (mainly NASA)-funded unit of the California Institute of Technology (www.caltech.edu)
- Charter: Un-manned (robotic) missions

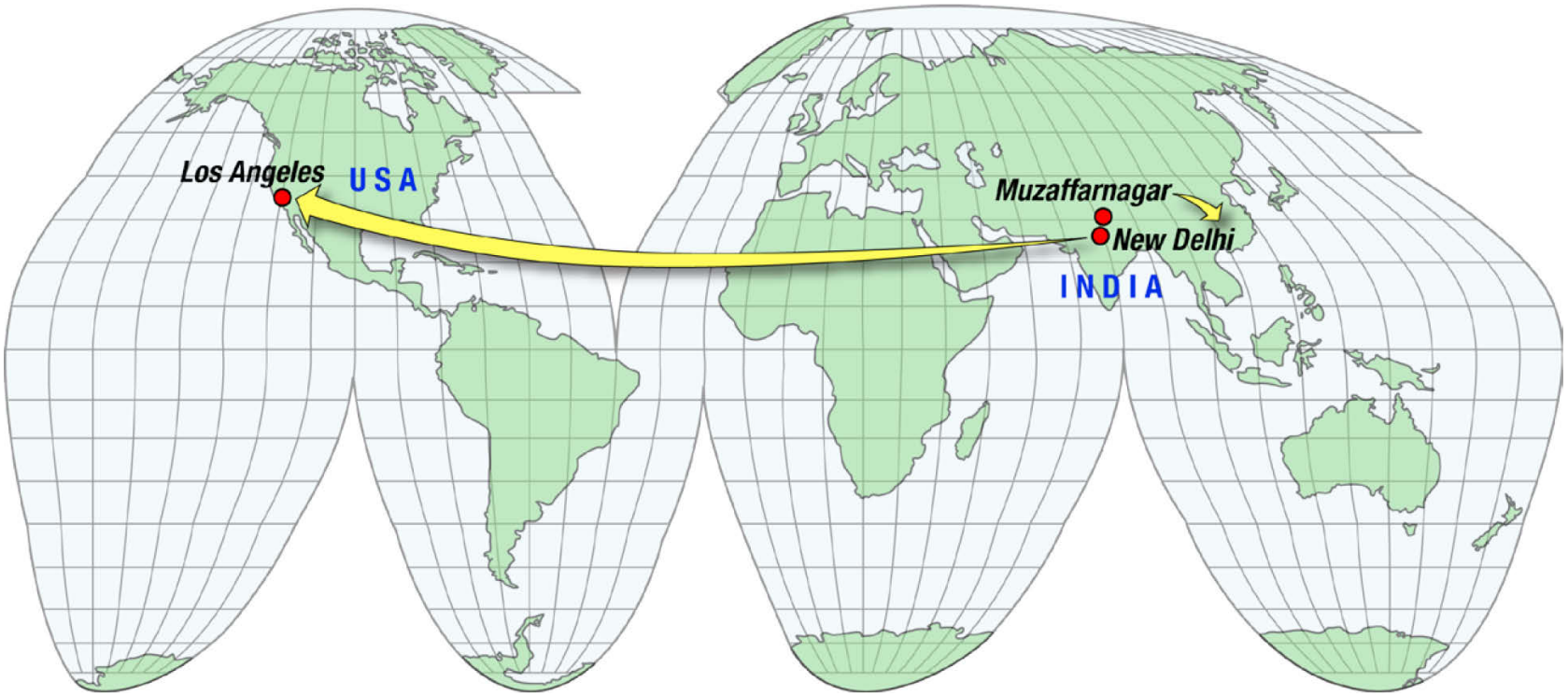
# NASA/JPL

- **Quest for Learning**
  - NASA Jet Propulsion Laboratory, my work place, is on a Journey – an **exploration**, a **quest for knowledge** – exploring Mars and other celestial bodies, looking back to Earth and seeing it better.
  - **Exploration** is traveling in or through unfamiliar areas to learn about them, investigation of unknown regions, seeing the universe without and within!
  - Of course, you need **parts** to get there. The Marines are looking for a few good men. We are looking for a few good parts.




*Launched June 10, 2011, the Aquarius/SAC-D mission is a partnership between NASA and Argentina's space agency, Comisión Nacional de Actividades Espaciales (CONAE) that will use advanced technologies to make NASA's first space-based measurements of ocean salinity across the globe.*

# An Individual Quest for Learning



# JPL MISSIONS IN FLIGHT

In this artist's illustration of the solar system, bodies such as planets, their orbits and spacecraft are not shown to scale.

## INTERSTELLAR SPACE

### Voyagers 1 and 2

**LAUNCH ▸ 8.20.77 AND 9.5.77**

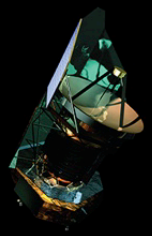
Flew by Jupiter and Saturn; Voyager 2 went on to Uranus and Neptune. Now nearing interstellar space.

## STARS & GALAXIES

### Herschel

**LAUNCH ▸ 5.14.09**

This European mission, with significant JPL involvement, uses infrared to explore the cold universe and the births of stars and galaxies.



### Kepler

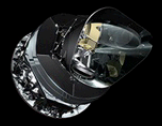
**LAUNCH ▸ 3.6.09**

Searching more than 100,000 stars for signs of Earth-like worlds.

### Planck

**LAUNCH ▸ 5.14.09**

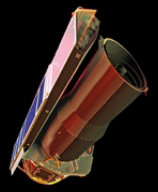
This European mission, with significant JPL involvement, is looking back in time to understand the very early evolution of the universe.



### Spitzer Space Telescope

**LAUNCH ▸ 8.25.03**

Uses infrared light to study the early universe and planets around nearby stars.



### Wide-field Infrared Survey Explorer

**LAUNCH ▸ 12.14.09**

This space-based telescope mapped the sky in infrared light, finding objects from near-Earth asteroids to the most luminous galaxies.

## COMETS & ASTEROIDS

### Dawn

**LAUNCH ▸ 9.27.07**

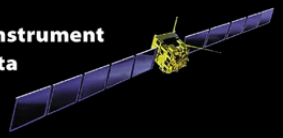
Orbiting giant asteroid Vesta through August 2012 and then on to dwarf planet Ceres.

## Deep Impact/EPOXI

**LAUNCH › 1.12.05**

Revealed the interior of a comet. On November 4, 2010, the spacecraft flew by and investigated comet Hartley 2.

## Microwave Instrument on the Rosetta Orbiter

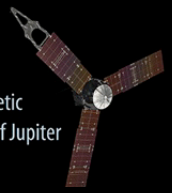


**LAUNCH › 3.2.04**

Will collect data about the nucleus of comet 67P/Churyumov-Garasimenko during Rosetta's 2014 encounter.

# JUPITER

## Juno



**LAUNCH › 8.5.11**

Will map the gravity field, magnetic field and atmospheric structure of Jupiter from a unique polar orbit.

# SATURN

## Cassini–Huygens

**LAUNCH › 10.15.97**

Exploring Saturn and its rings and moons. Delivered Huygens probe to Titan 1.14.05.

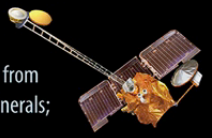
# MARS

## Mars Exploration Rover Opportunity

**LAUNCH › 7.7.03**

Finding clues about wet environments on ancient Mars.

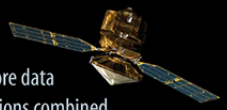
## Mars Odyssey



**LAUNCH › 4.7.01**

Looking for water and ice from orbit; studying surface minerals; relaying rover data .

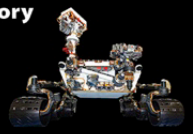
## Mars Reconnaissance Orbiter



**LAUNCH › 8.12.05**

Examining Mars in high resolution; has returned more data than all previous Mars missions combined.

## Mars Science Laboratory

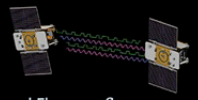


**LAUNCH › 11.26.11**

Delivering rover Curiosity to study whether Mars has offered environmental conditions favorable for microbial life.

# MOON

## Gravity Recovery and Interior Laboratory

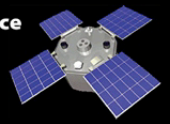


**LAUNCH › 9.10.11**

Twin spacecraft — named Ebb and Flow — fly in tandem around the Moon to precisely measure and map the Moon's gravitational field.

# EARTH

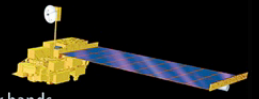
## Active Cavity Irradiance Monitor Satellite



**LAUNCH › 12.20.99**

Measures the amount of solar energy reaching Earth.

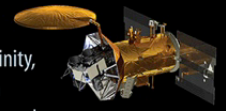
## Advanced Spaceborne Thermal Emission and Reflection Radiometer on Terra



**LAUNCH › 12.18.99**

Obtains high-resolution images of Earth in 14 color bands.

## Aquarius



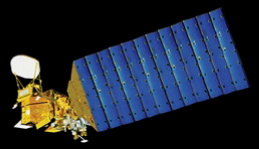
**LAUNCH › 6.10.11**

Measures ocean surface salinity, offering insights into ocean circulation, the global water cycle and climate.

### Atmospheric Infrared Sounder on Aqua

**LAUNCH ▸ 5.4.02**

Measures air and surface temperatures, humidity and clouds.



### Jason 1

**LAUNCH ▸ 12.7.01**

Monitors global ocean circulation by studying sea-surface height.

### Ocean Surface Topography Mission/Jason 2

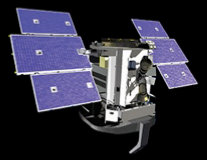
**LAUNCH ▸ 6.20.08**

Extends the Jason 1 climate record to continue the study of ocean circulation, climate change and sea-level rise.

### CloudSat

**LAUNCH ▸ 4.28.06**

Studies clouds on a global basis to contribute to better predictions of clouds and their role in climate change.



### Microwave Limb Sounder on Aura

**LAUNCH ▸ 7.15.04**

Measures vertical profiles of atmospheric gases, temperature and pressure.

### Quick Scatterometer

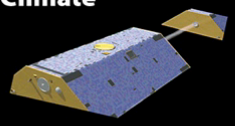
**LAUNCH ▸ 6.19.99**

Senses ocean surface ripples using radar pulses; data used to compute wind speed and direction.

### Gravity Recovery and Climate Experiment

**LAUNCH ▸ 3.17.02**

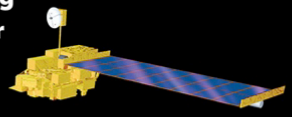
These twin satellites measure Earth's gravity field.



### Multi-angle Imaging SpectroRadiometer on Terra

**LAUNCH ▸ 12.18.99**

Images surface and atmospheric components from nine camera angles.



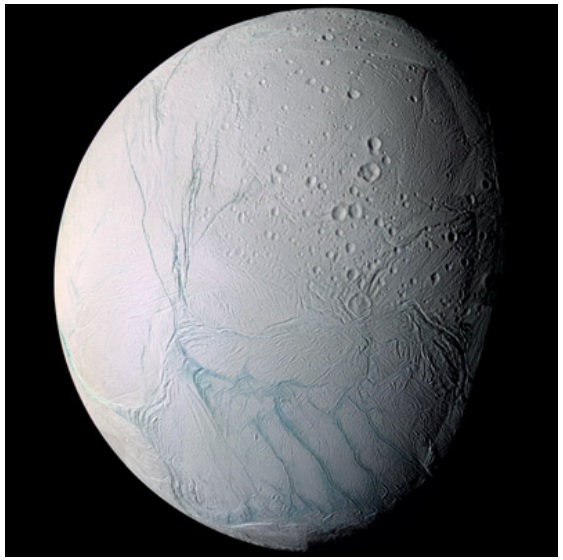
### Tropospheric Emission Spectrometer on Aura

**LAUNCH ▸ 7.15.04**

Studies the state and composition of Earth's troposphere, especially ozone.

# Electronic Parts for Deep Space Missions
# Some Considerations

- **Strive to save power; design-in low power parts**
- **Operate in space radiation environment; consider the effects of radiation**
- **Mission reliability; worse case analysis, derating**
- **Missions are Non-repairable; can't send a repairman up there**
- **Small, light weight packages**
- **Functional integration; use parts that offer high functionality**
- **Other, mission specific**



*The NASA/ESA/ASI Cassini-Huygens mission has directly sampled the water plumes jetting into space from Saturn's moon Enceladus. The findings from these fly-throughs are the strongest evidence yet for the existence of large-scale saltwater reservoirs beneath the moon's icy crust.*

# Electronic Parts for use in Space

- **Qualification is considered essential for most spaceborne electronic parts**
- **But what constitutes qualification?**
- **Ideally, qualification is a process that assures parts meet minimum mission requirements**
- **NASA's qualification requirements vary widely**
  - Different approaches used across NASA, influenced by traditional roles and changes to reflect new realities
- **MIL specification "Class S" probably comes closest to being the universally usable, space part**

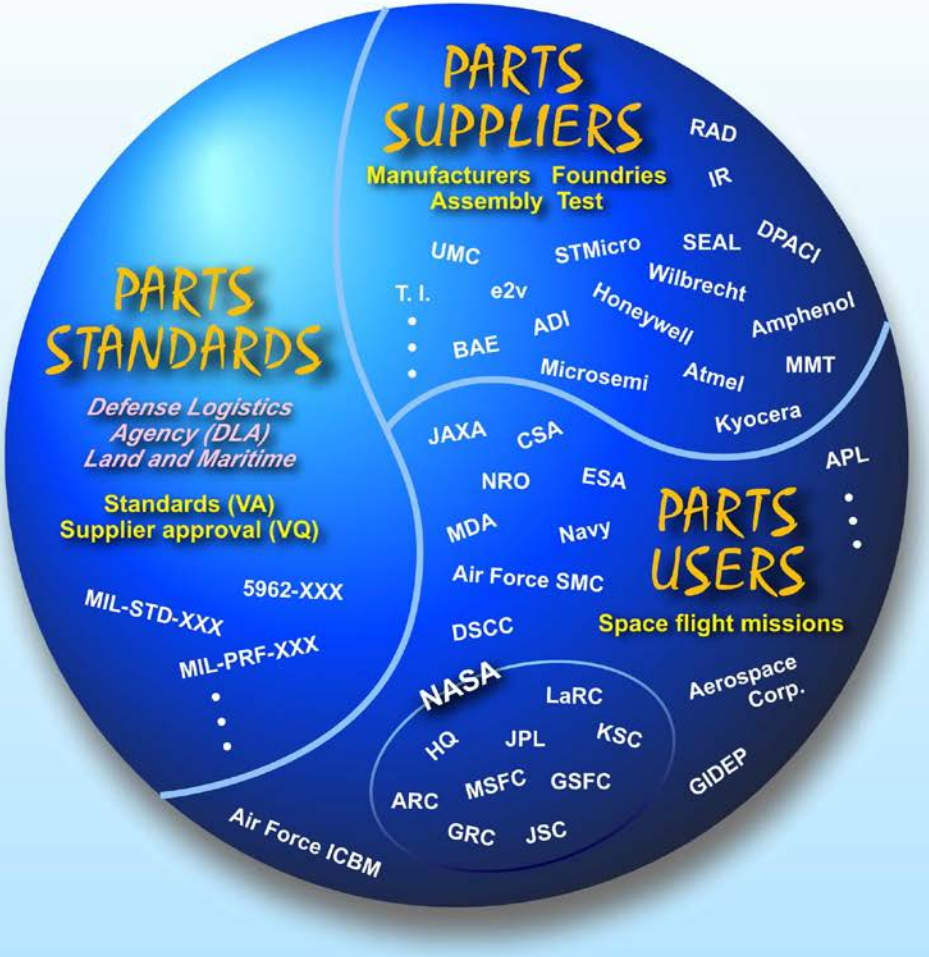
NEPAG = NASA EEE Parts Assurance Group
composed of 27 space organizations, including international space agencies

# Qualification Objectives

- **Ensure parts are suitable for the intended use**
- **Find the limiting weaknesses**
- **Test like we fly?**
  - Not so much at part level, significant margins employed to force out failures
- **Cover the maximum range of the key stresses seen in the system's applications + margin**
  - The MIL system's ranges of temperature, vibration, shock etc. do this very well for most space applications

The Hubble Space Telescope (HST) is a space telescope that was carried into orbit by a Space Shuttle in 1990 and remains in operation. A 2.4-meter (7.9 ft) aperture telescope in low Earth orbit,

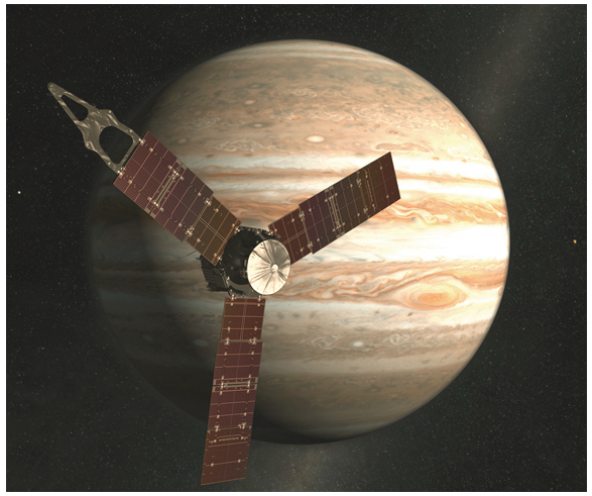
# Space Parts World
## A Small, Vanishing Part of the Commercial Parts World




NEPAG is actively involved with the procurement process - parts users and standards organizations join hands to ensure timely delivery of reliable parts from suppliers.

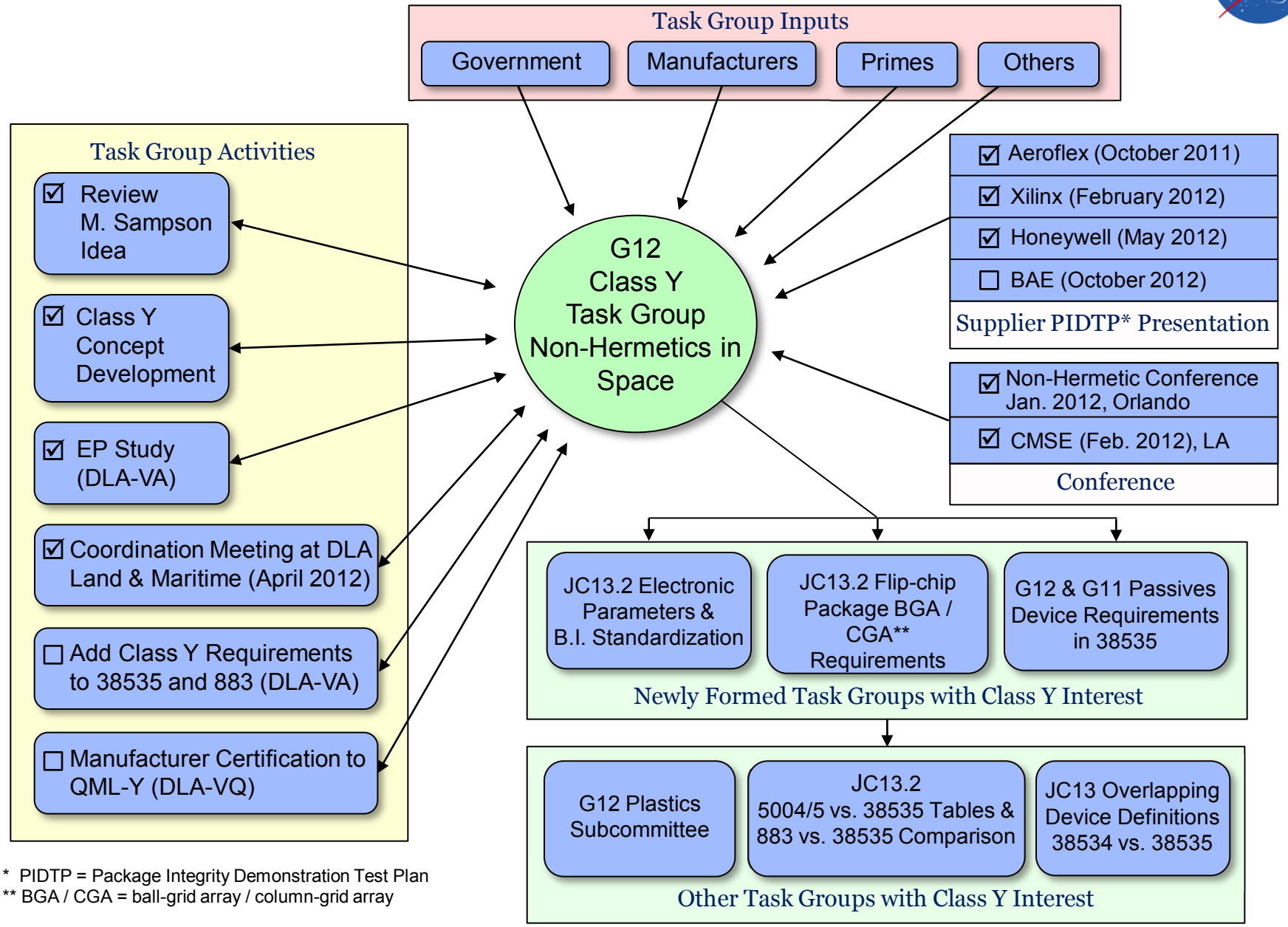
# Changing Landscape
# A New Trend – Supply Chain Management

| | |
|---|---|
| Die design | Manufacturer |
| Fabrication | Operation A<br>(could be performed by the manufacturer or Company A) |
| Package design<br>Package manufacturing | Operation B |
| Wafer lap and dice | Operation C |
| Assembly | Operation D |
| CGA column attach<br>Solderability | Operation E |
| Screening/electrical/package Tests | Operation F |
| Complete electricals per SMD | Operation G |
| Internal water vapor content | Operation H |
| Radiation testing | Operation I |
| And so on…… | |



*Launched in August 2011, the solar-powered Juno spacecraft enters a low, elliptical orbit circling Jupiter from pole to pole to investigate secrets hidden beneath the planet's thick, colorful clouds. The innovative orbit will avoid lethal belts of charged particles surrounding Jupiter like the less dense Van Allen belts encircling Earth.*

# Infusion of New Technology into the QML System
# G12 Class Y Effort at a Glance




* PIDTP = Package Integrity Demonstration Test Plan
** BGA / CGA = ball-grid array / column-grid array

# Future Space Missions

- **Integrated Circuit Issues**

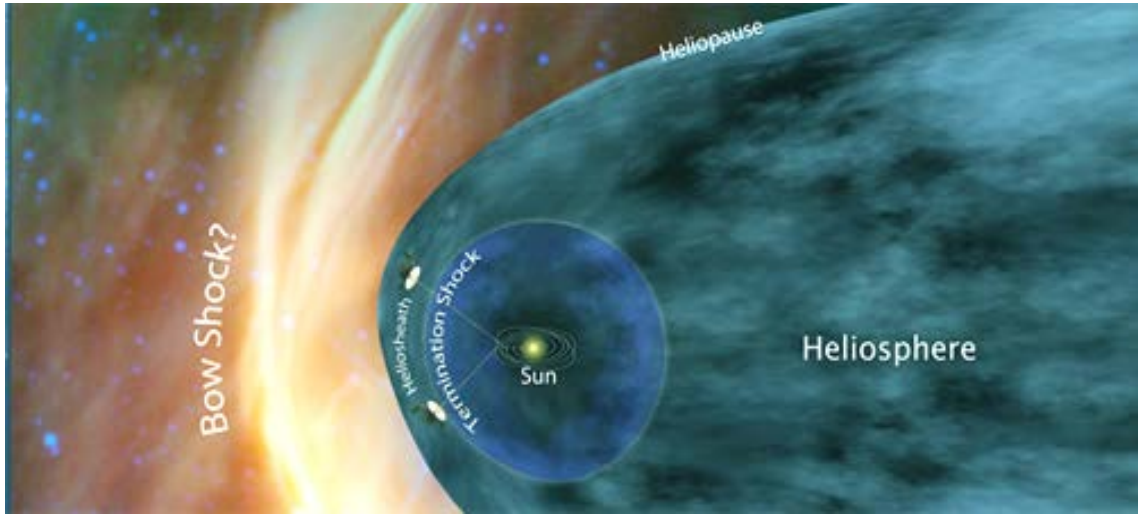
  - **Dual Use Technology.** Infusion of selected commercial device functions into QML system. Parts might not operate over full military temperature range. Moreover, there may be hot spots on the die.
    *Recommendation:* Review SMDs. Use techniques such as thermal imaging to look for hot spots and make necessary adjustments to thermal resistance values.
  - **Testing high-speed and high-resolution A/D converters.** Would be challenging for users to perform reliability and radiation-testing.
    *Recommendation:* Consider forming consortia with manufacturer and other users. Request new JEDEC task group be started to address this challenge – what can be tested, how, and what is good enough?
  - **Upscreening of plastic encapsulated microcircuits (PEMs), lower grade hermetic analog and mixed signal parts.** Many challenges: electrical testing, type of burn-in, glass transition temperature (for PEMs), third-party management, etc.
    *Recommendation:* Ask manufacturer if they would consider doing it (sufficiently high quantities might justify it). Form consortia. Consider application-specific testing.
  - **Counterfeit Parts.** World-wide problem.
    *Recommendation:* Buy parts from franchised/authorized distributors.
  - **Supply Chain Management.** Self audits are an issue.
    *Recommendation:* Work with DLA Land and Maritime. Handling and electrostatic discharge (ESD) issues take on increasingly important role.

# Future Space Missions (contd.)

- **Integrated Circuit Issues** (Contd.)
  - **New technology evaluation.** How to evaluate?
    *Recommendation:* Use MIL-PRF-38535, Appendix H. Some suppliers perform wafer-level reliability (WLR) assessment as well.
  - **New package configurations; e.g., CGAs (Column Grid Arrays).** Parts standardization effort has severely lagged behind advancements in packaging technology. A/D suppliers have announced products in CGA configuration but no mil standards are in place to establish requirements after columns have been installed. Are CGA parts an assembly, rather than a part? Often, users buy LGAs (Land Grid Arrays) and then get the columns attached.
    Status/*Recommendation:* JEDEC task group is addressing CGA issues. DLA audit team is discussing CGA issues with suppliers. Use caution when buying LGAs and getting columns installed – original manufacturer's warranty may become void.
  - **Signal-integrity capacitors for high-speed A/D converters.** For signal-integrity considerations, tiny low-voltage capacitors are used inside IC packages. Usually commercial capacitors of BME (base metal electrode) construction.
    Status*:* JEDEC task group addressing screening and qualification requirements for BME capacitors.
  - **New materials.** Materials such as underfills used in new packages would need to be evaluated.
    Status*:* JEDEC task working on updating requirements in MIL-STD-883, Test Method 5011.

# Future Space Missions (contd.)

- **Integrated Circuit Issues** (Contd.)
  - **Budgetary Pressures.** Will continue – particularly challenging for high-reliability, non-repairable missions.
    *Recommendation:* Form consortia. Discuss on NEPAG telecons.
  - **Implementation of requirements.** Do the tests/screens done meet the intent of specification?
    *Recommendation:* Perform audits as necessary.




*The twin Voyager 1 and 2 spacecraft continue exploring where nothing from Earth has flown before. In the 33rd year after their 1977 launches, they each are much farther away from Earth and the Sun than Pluto. Voyager 1 and 2 are now in the "Heliosheath" - the outermost heliosphere layer where the solar wind is slowed by interstellar gas pressure. Both spacecraft still send back scientific information about their surroundings.*

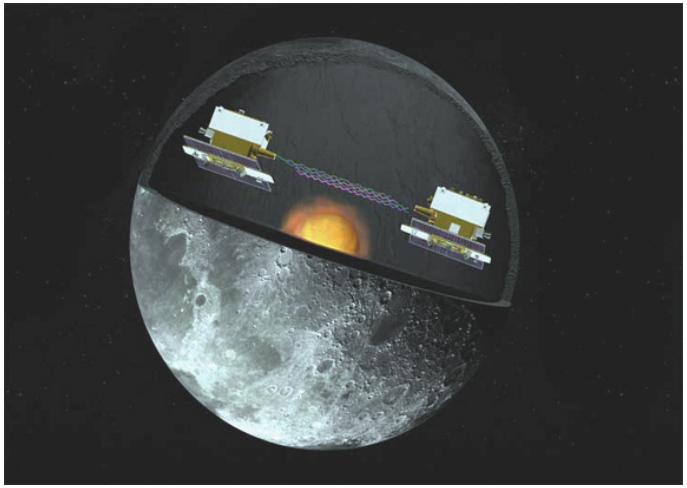
# Future


- **Who knows? BUT it will be:**
  - Smaller and lighter
  - More efficient
  - Faster
  - Changing continuously
  - Desirable BUT perhaps not space-worthy
  - And someone always expects it to be more affordable
- **And we need to be:**
  - Flexible and innovative
  - Open-minded
  - Willing to expand the definition of "part" as integration puts more system levels on a chip or in a package

Business as Usual – JUST EVEN MORE COMPLEX

# Conclusion

- Challenging times ahead for mission assurance
- Budgetary constraints
  - Do more with less
  - More so, for non-repairable missions
- Communication
  - CICC
  - NEPAG
  - JEDEC
  - Other means
- Flexibility needed
  - Especially when it comes to adapting new technology



*Gravity Recovery and Interior Laboratory (GRAIL) mission, using twin spacecraft flying in formation to investigate the moon's gravity field, a possible inner core and how Earth and other rocky planets formed, was launched in late 2011.*

*Happy sailing to new discoveries!*

Thank you!

The research described in this publication was carried out, in part, at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. Help is gratefully acknowledged from Dr. Charles Barnes, Roger Carlson, Joon Park, and Michael Sampson.

# Exploration Videos

- **All travelers have pictures of their trips. NASA is no exception. Here are three vignettes from exploring Earth, selecting the best place to investigate on Mars, and the Mars landing.**
  - **Aquarius Spacecraft for Earth-oriented science**

    http://www.jpl.nasa.gov/video/index.cfm?id=984
  - **Selection of Mars Science Laboratory (MSL) Landing Site**

    http://www.jpl.nasa.gov/video/index.cfm?id=1005
  - **7 Minutes of Terror (MSL Entry, Descent, and Landing)**

    http://www.jpl.nasa.gov/video/index.cfm?id=1090