ANALOG AND MIXED SIGNAL ICs
for use in
FUTURE SPACE MISSIONS

Fourth International Workshop on Analogue and Mixed Signal Integrated Circuits for Space Applications

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

INTRODUCTION

- Before addressing the use of analog and mixed signal devices in future space missions, this paper examines the status of standards and specifications being used today: are the requirements therein clearly stated and followed correctly? (Not really, especially when it comes to burn-in screening of parts used to remove infant mortality.)
- About 12 years ago, the space parts users formed NASA EEE Parts Assurance Group, NEPAG, on the premise to connect and to communicate. There are currently 27 organizations that are part of it including our international partners, the European Space Agency (ESA), Japan Aerospace Exploration Agency (JAXA) and Canadian Space Agency (CSA).
- Some of the key NEPAG activities are: weekly telecons (monthly with international partners), participation in supplier audits worldwide, review of pre-released specifications, working with JEDEC community on parts issues (week-long meetings held three times a year).
- Next we'll give details of some of the findings and steps being taken to fix the shortcomings identified by audits and specification reviews.

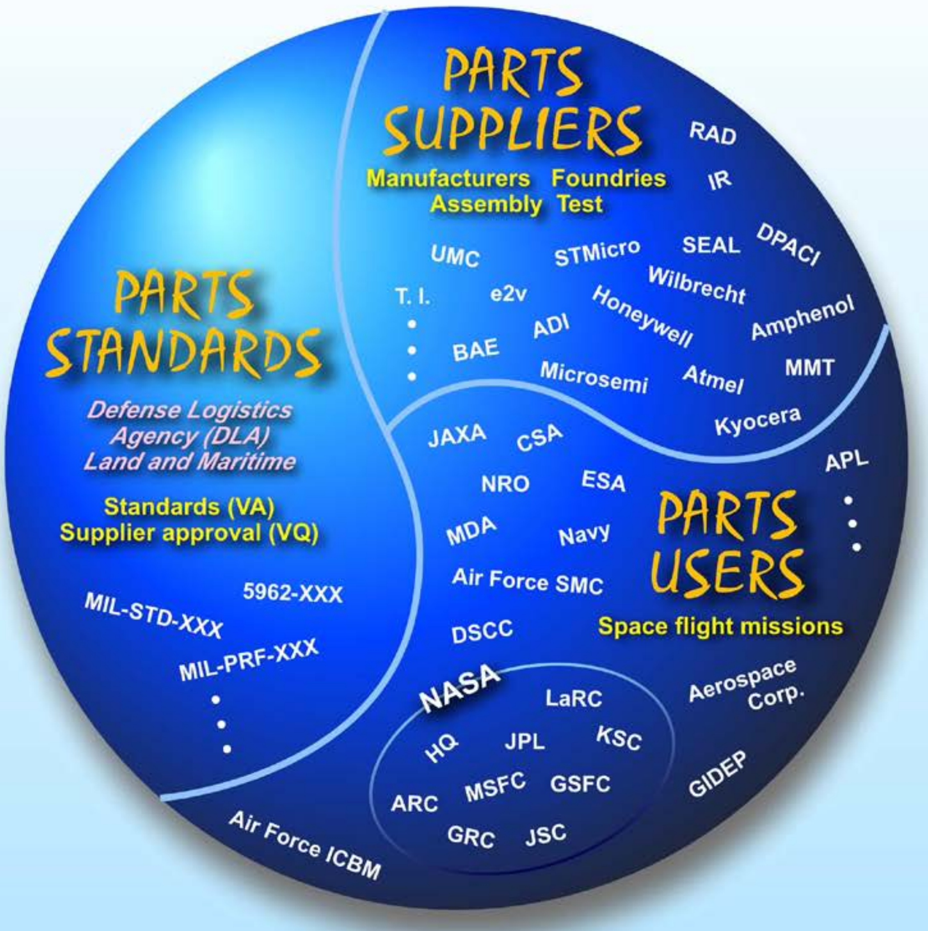
INTRODUCTION (Contd.)

- There are new challenges of dual use technology, supply chain management, changing business models – the changing landscape. For instance, many newer analog-to-digital (A/D) converters are being offered as column grid arrays (CGA). However, the military standards are silent on proper testing, inspection, application requirements and guidelines for CGAs.
- There are issues related to the infusion of new state-of-the-art devices into the military system. Advancements in packaging technology and increasing functional density and operating frequency have resulted in single-die system-on-a-chip (SoCs) with non-hermetic flip-chip construction, in high-pin-count packages. Such devices did not fit existing QML classifications. We'll touch upon the efforts for bringing them into the standardization (QML) system.
- The last few pages will provide some thoughts on the use of analog and mixed signal microcircuits in future space missions.

NASA EEE Parts Assurance Group (NEPAG)

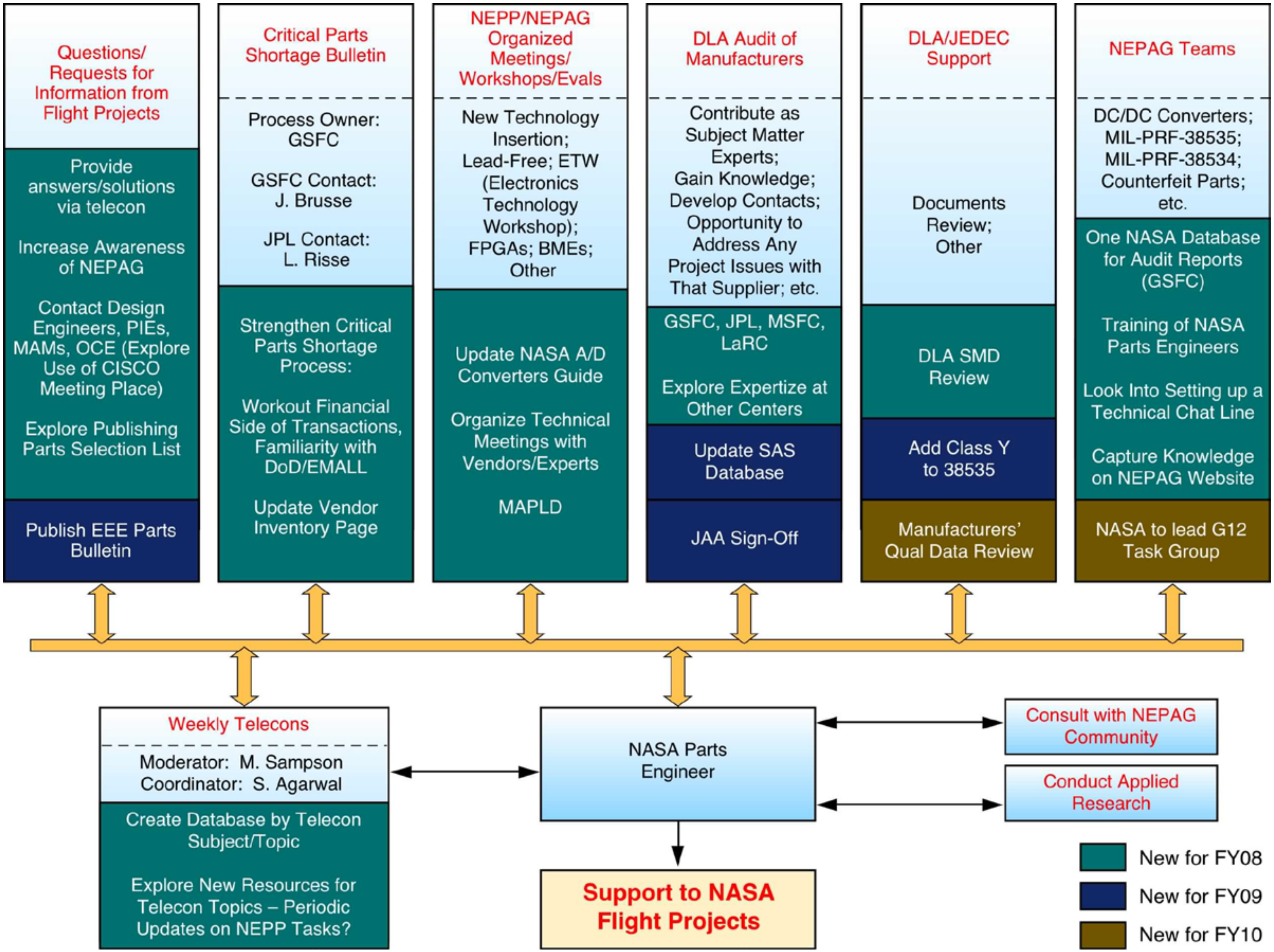
NEPAG PARTICIPANTS

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.

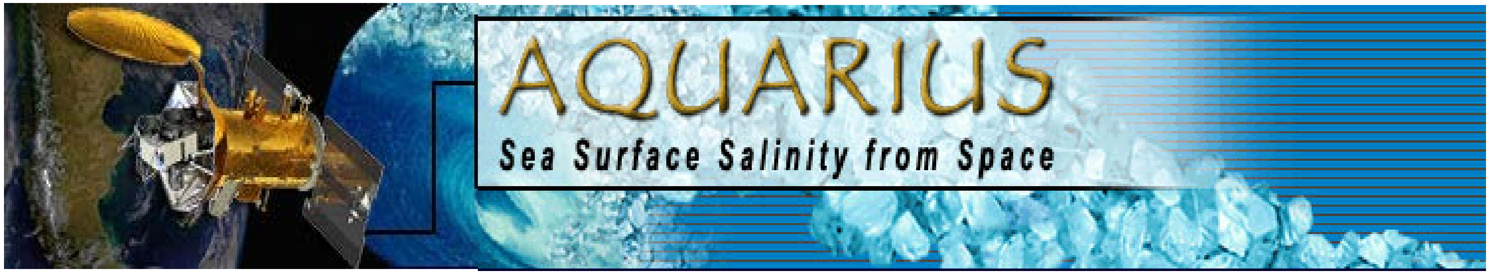
NEPAG ACTIVITIES



NEPAG

Standard Microcircuit Drawing (SMD) REVIEWS

- **NASA Review of Pre-released SMDs for Space Products**
  - Understanding between NASA and DLA Land and Maritime-VA: NASA to provide comments within 10 days.
  - NASA comments considered essential by DLA Land and Maritime.
  - The in-house experts (parts specialists, radiation specialists, packaging specialists, reliability engineering, and others) are called upon to support this effort.
  - New technology data review
    - Suppliers using MIL-PRF-38535, Appendix H for dual-use technology
    - Commercial parts developed for space customers
    - An early NASA and space community involvement in new product definition, SMD development



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.

NEPAG
SUPPLIER AUDITS

- **DLA Audits Support**
  - DLA Land and Maritime-VQ (formerly DSCC) is the designated Department of Defense entity that has **authority to approve or disapprove suppliers**. There are two parts to an audit: certification (capability demonstration) and qualification (successfully building product).
  - Agencies such as NASA and the Air Force bring **technical expertise** to audits.
  - Audits to be supported by space community are **decided on the NEPAG telecons**. We support audits as subject matter experts, gain personal knowledge, make contacts, and **resolve flight project issues.**
  - Audit team spends most of audit time on production floor, test floor, etc. to talk to operators, engineers, and witness operation or tests being performed. Review supplier chain management, counterfeit parts mitigation, and other items.
  - Audit findings reported on NEPAG telecons. High-level summary of audits supported by NASA entered into NASA **SAS** (supplier assessment system) database.

Recent Findings

- **Microcircuits**
  - Recent Findings from Audits, New Technology Data Reviews
    - **Disabled Chip Burn-ins.** Recent audit for QML device discovered chip was disabled during static burn-in; thus, it was not drawing any current.
      Recommendation: For new SMDs, add statement within burn-in paragraphs stating that parts shall be kept in their enabled state during burn-in.
    - **Class Q 160-hr/125ºC Burn-in.** Interpreted as static burn-in (even for CMOS technology).
      Recommendation: Provide clarification in MIL-STD-883, Test Method 5004.
    - **At Frequency (Dynamic) Burn-ins.** Test equipment limitation cited for not doing burn-ins at application frequency.
      Recommendation: Burn-in task group to discuss and provide guidance. When SMD says that part can be used at 200 MHz, doing burn-in at 6 MHz (cited as burn-in equipment limitation frequency) is not going to be meaningful!
    - **Two Static Burn-ins.** Some manufacturers do electrical testing between two static burn-ins, whereas others do electricals after completing both static burn-ins.
      Recommendation: Provide clarification in MIL-STD-883, Test Method 5004.
    - **Thermal Imaging.** For a device with hot spots, thermal resistance, junction-to-case would be much higher than guidelines in MIL-STD-1835. One supplier used thermal imaging to find hot spots on the die.
      Recommendation: Assign a task group to evaluate effectiveness of thermal imaging at product development stage.

Task Group- 2011-01
SMD Electrical and Burn-in Guidelines

- **Charter for Task Group.** Develop JEDEC document for guidance to suppliers and users that includes recommendations on Deltas, SMD electrical parameters, and Burn-in. Also, provide recommendations for any needed changes to MIL-STD-883.

1. Burn-In

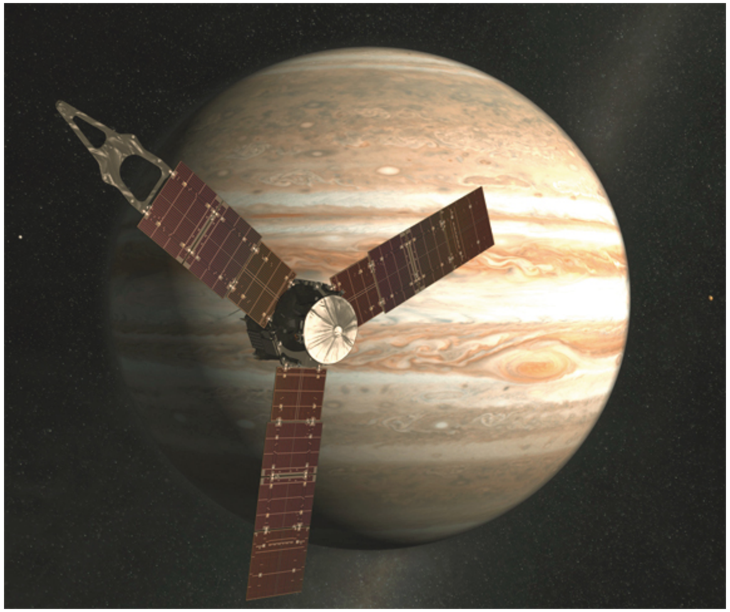
a. types required - dynamic and static/high-temperature reverse-bias burn-in (HTRB)
b. burn-in specified by technology or product type
c. junction temperatures to be achieved
d. burn-in conditions - voltages, frequency, etc.

2. Delta Requirements

a. definition - critical parameters selected to provide a measure of product and process stability
b. selection of delta parameters

3. Electrical Measurements

a. parametrics
b. functional
c. selection of limits based on ???
d. parameters guaranteed
    1) but not tested
    2) by design
    3) by characterization data
    4) data required to validate guaranteed position



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.

NASA Inputs to B.I. Task Group

1. **Clarify burn-in requirements for space products in Table I of Method 5004: specifically, screening steps 3.1.10, 3.1.12, footnote 9/ and footnote 10/.** As written, it implies that dynamic burn-in is a requirement. However, it is not always done. Moreover, for certain functions, such as a precision voltage reference, how would you design a dynamic burn-in? Requirements need to be reviewed and updated.

2. **HTRB vs. Static Burn-in.** No mention of Static burn-in in Table I of Method 5004. We all know that digital products are subjected to Static burn-ins, often two: one for low condition (Static I) and the other for high condition (Static II). Add reference to static burn-in(s) as appropriate.

3. **How are burn-in voltage, frequency, etc. supposed to be determined?**

4. **Are any manufacturers using low temperature burn-in?** If yes, low-temp burn-in option should be included in screening spec.

5. **What Ea should be used for new technology?** Some manufacturers are using a fixed activation energy (Ea) of 0.7 eV.

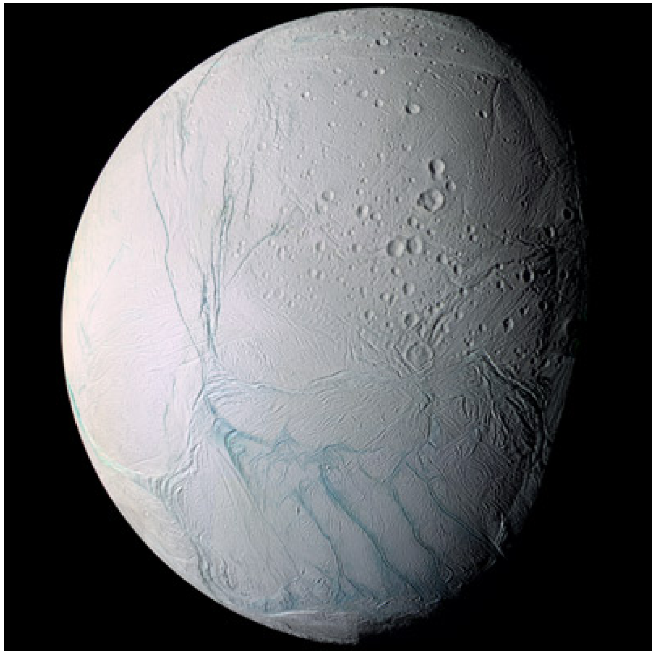
6. **Time-temperature regression tables, e.g. Table I in Method 1015, should be reviewed.** What Ea are they based on? Is that still valid?

NASA Inputs to B.I. Task Group (contd.)

7. Restricted temperature parts: What and how are burn-in temperatures determined?

8. Dynamic burn-in for high-speed devices. What frequency should be used?

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.



Changing Landscape
A New Trend – Supply Chain Management

Die design	Manufacturer
Fabrication	Operation A (could be performed by the mfr or Company A)
Package design Package manufacturing	Operation B
Wafer lap and dice	Operation C
Assembly	Operation D
CGA column attach 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………

Changing Landscape
Operating Temperature Range, Use Caution
Many newer parts no longer guaranteed over mil temp range

Example: DLA SMD 5962-99607

Device type	Generic number	Circuit function	Access time
01	8Q512	512K X 8-bit rad-hard low voltage SRAM (MIL Temp)	25 ns
02	8Q512	512K X 8-bit rad-hard low voltage SRAM (Extended Temp)	25 ns
03	8Q512	512K X 8-bit rad-hard low voltage SRAM (MIL Temp)	20 ns
04	8Q512	512K X 8-bit rad-hard low voltage SRAM (Extended Temp)	20 ns
05	8Q512E	512K X 8-bit rad-hard low voltage SRAM (MIL Temp)	20 ns
06	8Q512E	512K X 8-bit rad-hard low voltage SRAM (Extended Temp)	20 ns

Operating case temperature, (T_C) (Device 01, 03, and 05) .... -55 ºC to +125 ºC
Operating case temperature, (T_C) (Device 02, 04, and 06) .... -40 ºC to +125 ºC

This SMD is implying that there may be a performance issue at low temperatures. Use caution for operation at low temperatures. Work with the manufacturer, get product test/characterization data.

Some other Memories (e.g., 5962-01533 and 5962-01511) are specified as follows:
- **Device type 01, -40 ºC to +125 ºC;**
- **Device types 02 and 03, -40 ºC to +105 ºC.**

These may have performance problems at both low and high ends.

Infusion of New Technology Devices into QML, Class Y

Status: DLA-VA's Engineering Practice (EP) Study for Class Y is **complete**

Background

In 2009, big push to bring the Xilinx Virtex-4 (a non-hermetic part) into QML system as Class V device. NASA and others were not in favor; it would have created massive confusion. Mike Sampson conceived idea of new Class Y for non-hermetic space parts to provide QML coverage for complex state-of-the-art devices.

New G-12 Task Group, TG 2010-01, formed in early 2010 to address non-hermetic devices for space. Shri Agarwal was asked to lead.

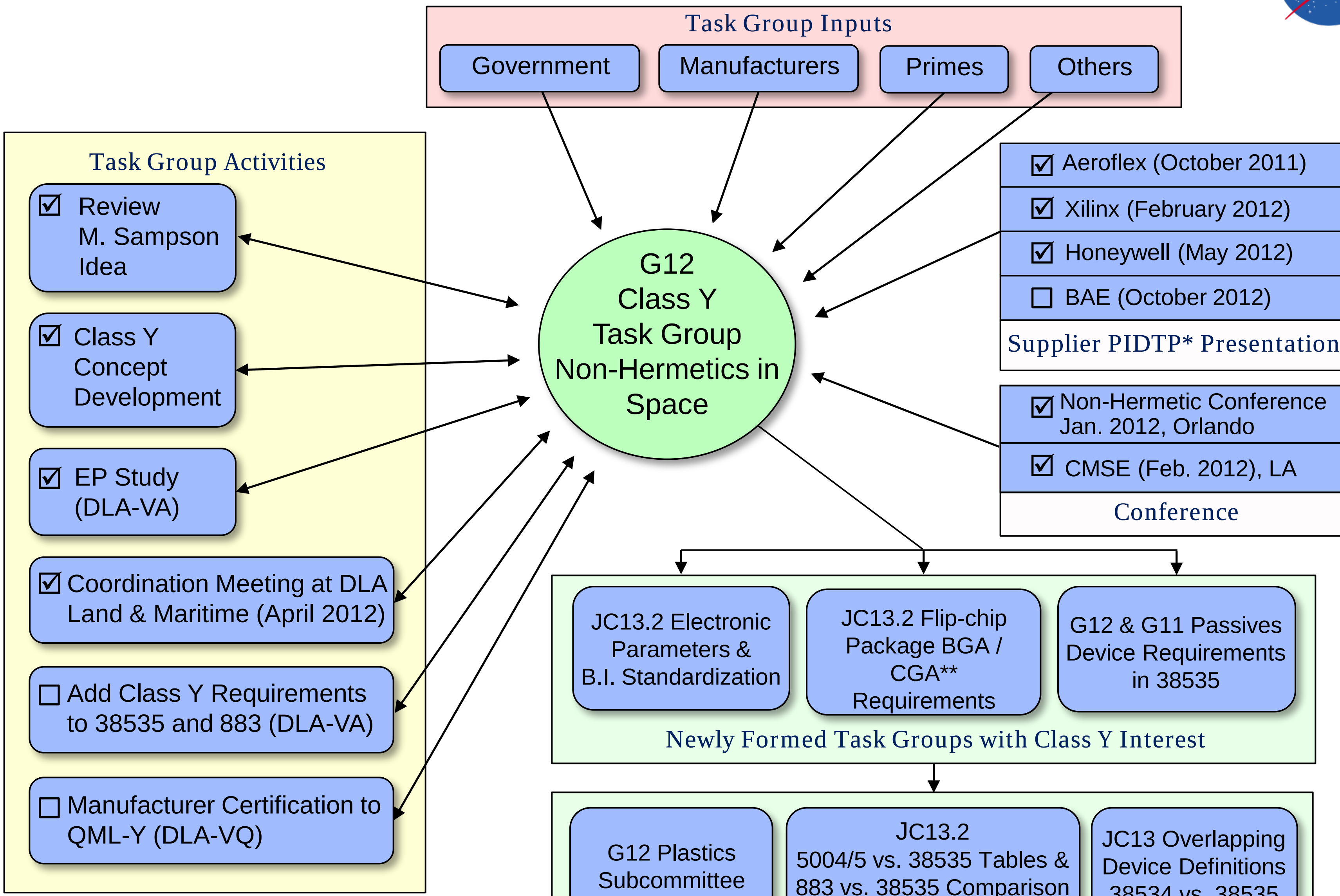
Challenging task:

- Far more involved than typical G12 tasks
- Required development of new concept
- Used system-on-a-chip (SoC) — one of the most complicated devices
- Needed to be simple and easily understood
- Possessed sketchy testing and board assembly boundaries
- Needed to procure standard QML product as quickly as possible.

New QML Class "Y"

- An attempt to bring advancements in packaging technology into QML system.
- Advancements in packaging technology and increasing functional density and operating frequency have resulted in single-die SoCs with non-hermetic flip-chip construction, in high-pin-count ceramic column grid array packages
  - "Poster Child" example: Virtex-4 (V-4) FPGAs from Xilinx
  - Such products were evaluated for radiation and reliability; have drawn attention of the space user community
- Question: How do we bring V-4 and similar microcircuits into QML system as space products?
  - Can't be Class V – those are hermetic devices
  - Intend to put V-4 like products for space users in a new category: "Class Y".
  - G-12 opened Task Group to develop Class Y
- What if we dropped Class Y effort?
  - Would be major loss for space community and QML program at large because industry would be limited to ordering via Source Control Drawings (SCDs) – counterproductive to Mission Assurance, prevents standardization, and is expensive.

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

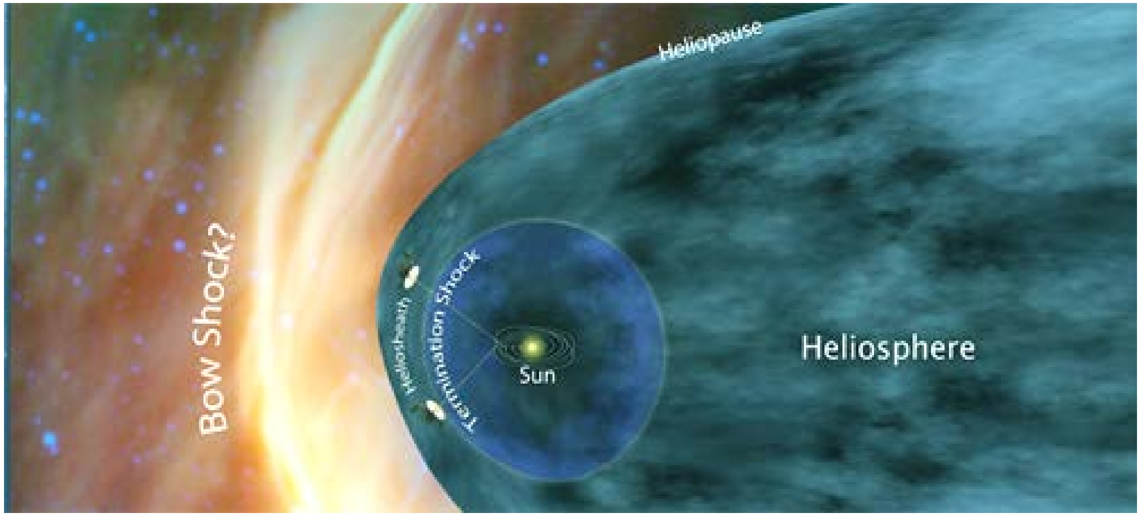
- **Analog and Mixed Signal Devices**
  - Some Challenges
    - **Dual Use Technology.** Infusion of selected commercial device functions into QML system. Parts might not operate over full military temperature range. Moreover, there may be hot spots on the die.
      Recommendation: Review SMDs (see slide 15). 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 (see slide 14).
      Recommendation: Work with (in case of the United States) DLA Land and Maritime. Handling and electrostatic discharge (ESD) issues take on increasingly important role.

Future Space Missions (contd.)

- **Analog and Mixed Signal Devices**
  - Some Challenges (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.)

- **Analog and Mixed Signal Devices**
  - Some Challenges (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.



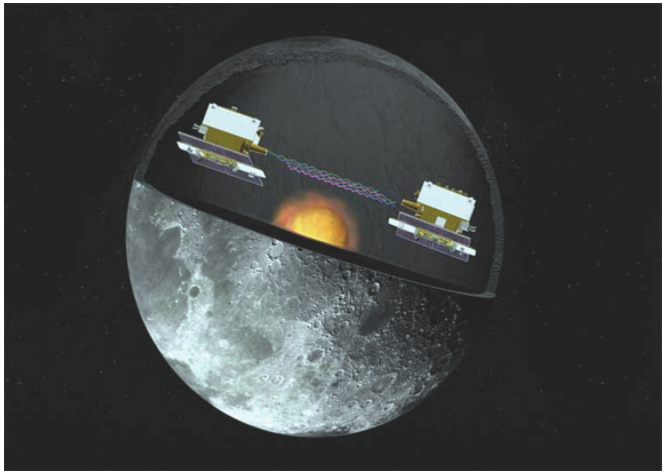
The twin Voyager 1 and 2 spacecraft continue exploring where nothing from Earth has flown before. In the 33rd year after their 1977 launches, they each are much farther away from Earth and the Sun than Pluto. Voyager 1 and 2 are now in the "Heliosheath" - the outermost heliosphere layer where the solar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

Conclusion

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

Note: For updated A/D tables, refer to NSREC 2012, poster paper W14.

Thank you!



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.