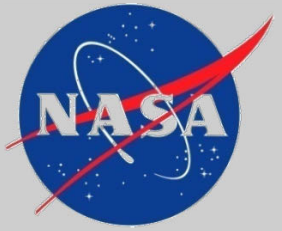
Japan Aerospace Exploration Agency (JAXA)
The 24th Microelectronic Workshop (MEWS24)
October 13, 2011

National Aeronautics
and Space Administration



Qualification Of Complex Devices – NASA Approach

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Agenda

- *Introduction*
- *Meaning of Qualification*
- *New Technology requirements*
- *Concerns and their mitigation*
- *Bringing New Technology into the QML System – The Class Y Initiative*

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.

Introduction

- Thank you Tamura-san and JAXA for your invitation. Tsukuba is a special place and I am very pleased to be here.
- JAXA is our valued partner and we appreciate their participation in NASA EEE Parts Assurance Group (NEPAG) activities
- Mike Sampson got preoccupied at the last moment so I'll be doing this NASA presentation on his behalf.
- This talk is about NASA perspective on qualification of complex devices.
- It is divided into four sections
  - NASA view of "Qualification"
  - Requirements as given in Appendix H
  - Concerns with Appendix H data and addressing those concerns
  - Infusion of state of the art complex devices into the QML system – the Class Y initiative

Dictionary

The 2 most relevant definitions:

Qualification:

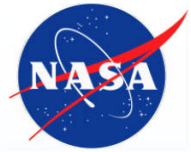
1. A condition or standard that must be complied with
2. A restriction in meaning or application : a limiting modification

http://www.merriam-webster.com/dictionary/qualification

Space Qualification

- 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
  - Minimum: it said "space qualified" in the catalog
  - Maximum: long and costly, multi-discipline evaluation and testing, of the part, the packaging and the radiation effects, based on a "recipe"
  - 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
  - European Space Agency (ESA) and Japanese Aerospace Exploration Agency (JAXA) qualified parts essentially equivalent
  - TOR compliant SCDs may be superior for military space applications

NEPP's Role



- **NEPP DOES NOT Qualify Electronic Parts**
- **NEPP Evaluates Electronic Parts Technologies**
  - **To identify strengths and weaknesses**
  - **To identify gaps in available test and inspection methods needed for the technology**
  - **To modify or develop tests and inspections to fill the gaps**
  - **To provide guidance for appropriate tests and inspections to select from and use for qualification for different mission needs**

Why is Qualification Important?

- Increases probability of success
- Provides a known design margin to worst case application conditions
- Establishes a formal process so lessons can be understood, learned and tracked
- Parts that fail to meet qualification requirements can be fixed or mitigated before being installed in hardware, thus avoiding expensive rework
- Provides data to support specification changes
- Provides a benchmark for part performance

Qualification DOES NOT GUARANTEE all lots will meet the requirements for ever and ever

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 <u>most</u> space applications

Spacecraft Versus Launch Vehicle

Overstatements with a Grain of Truth:

- **Expendable Launch Vehicle (Unmanned)**
  - **It Only Has to Last 30 Minutes**
- **National Asset Spacecraft (Hubble, Mars Science Lab)**
  - **One Strike and You Are OUT**
  - **Does it Pass the Front Page of the Post Test?**

OR

- **Science Spacecraft (regular)**
  - **It Must Meet Minimum Science Requirements (including life)**
- **Science Spacecraft (high risk or technology demonstrator)**
  - **We Want It to Work**
  - **It MUST Do No Harm**

AND

- **Expendable Launch Vehicle (Manned)**
  - **It MUST Work and work for days to cover emergencies**

These Principles Drive Parts Selection and Qualification

Space Qualified-The Facts

- There is NO SUCH THING AS NASA SPACE QUALIFIED
- JAXA and ESA have Agency-level specifications and therefore do Space Qualify, NASA does not
- NASA qualifies for the mission
  - It is impractical and unaffordable to try to cover all possible worst case conditions a part might see, in order to "Space Qualify" it for all missions
- Please stop using "Space Qualified" without attribution
- It is probably OK to say:
  - JAXA or ESA Space Qualified to Specification XYZ123
- It is OK to say:
  - Qualified to MIL-PRF-38534/38535 Space Level Class K/V
  - Qualified to Aerospace TOR XYZ
- It is also OK to say:
  - Qualified for use by NASA Project ABC
  - Qualified to NASA MSFC Specification 40M38298
- It is NOT OK to just say Space Qualified or NASA Qualified

And Then There Is …

- **HERITAGE**
  - It has flown before
  - It has been selected for a flight application – has NOT flown

AND

- Qualification by Similarity

Both can be legitimate and acceptable BUT:

- It's not about the part, it is about the application
  - Is the acceptable risk level the same or higher?
  - Is the operating environment the same or more benign?
  - Is the redundancy the same?
  - Is it being used in the same way?
  - Etcetera?

MIL-PRF-38535J, Appendix H

- Went through a complete revision (L. Harzstark led the effort)
- Gives a baseline that includes details of the certification, validation, and qualification programs.
- The necessary characterization, screening, and qualification testing applicable to new technologies is also included.
- Overview of QML Approval Process (H.3.1.9)
  - Design, wafer fabrication, assembly, and test certification
  - Physics of failure/Technology Characterization Vehicle (TCV) reliability assessment
  - Process technology validation/Standard Evaluation Circuit (SEC) qualification
  - Product qualification (From existing qualified process technology)
  - Standard Microcircuit Drawing (SMD)
  - QML listing
- This appendix is mandatory
- Manufacturer's Technical Review Board (TRB) plays an important role

Some Concerns

- 4000 hours life test as specified for QMLV products may not be long enough to show product failures
- No clear guidance on the type of circuit used for life test
- The manufacturers are performing 4000 hour tests and if there are no rejects they default to the activation energy of 0.7eV.
- Some questions:
  - Is 0.7eV still the right activation energy to use for scaled microcircuits
  - What parameters are monitored during the life test
  - Do the acceleration tables given in MIL-STD-883 still hold for new technology
  - Which circuit, static or dynamic, is right by product function/technology
- Restricted temperature range products
  - Many new technology products are being specified over narrower operating temperature range because they not producing sufficient yields over the full military temperature
  - What are the guidelines for their burn-in/life test temperature

Some Concerns (Contd.)

- *Solder terminated parts (could be hermetic or non-hermetic) need attention. Some specific questions are:*
  - *What is the shelf life of the CGAs?*
  - *Storage of the CGAs?*
  - *Do all internal and external portions of the flip-chip package pass MIL-STD-883, Method 5011?*
  - *Functional testing of the finished CGAs.*
  - *What board/assembly level test have been run for temp cycling/vibration, etc.*
  - *What is the max no. of allowable column reworks for space products?*
  - *Specify column pull test*
  - *Inspection of CGAs (area arrays, in general)*
  - *Need application notes on CGAs after column attach.*
  - *Coordination with IPC – what are the boundaries that separate JEDEC work from IPC?*

Some Concerns (Contd.)

- *The screening/qual requirements for signal conditioning capacitors should be clearly stated – ref. MIL-PRF-38535, Paras 3.15 and 3.15.1. What is the attached method of the BME capacitors used in many designs? During the G12 we heard couple of companies say they use epoxy or silver glass die attachment material to adhere the capacitor to the internal portion of the IC package. There are others who only use solder attachment. A JC13 Task Group has been formed to address these issues.*
- *What is a space flight part?*
  - *Land Grid Array, LGA, configuration (yes)*
  - *Column Grid Array, CGA, configuration (debatable)*
- *What are the boundaries between 38534 (hybrid) and 38535 (microcircuit) products?*
- *Can the differences between screening and QCI tables as specified in MIL-STD-883 and MIL-PRF-38535 be resolved?*
- *Where do the ceramic based non-hermetic parts such as the Xilinx Vitex-4 FPGAs fit in?*
  - *Can't be QMLV.*
  - *Propose a new QML class , Class Y.*
- *Will the set of 38535 classes, with Class Y added, cover microcircuits for the next several years? (yes, per the poll taken of major manufacturers)*

Addressing the concerns

- **Several Task Groups are working/starting to look into the before mentioned concerns**
  - **Class Y**
  - **Solder terminations**
  - **Burn-in, electricals, deltas**
  - **38534 and 38535 definitions**
  - **883 vs 38535 screening/QCI tables**
  - **Signal conditioning capacitor requirements**
  - **PEMs – CSAM and other inspection methods**

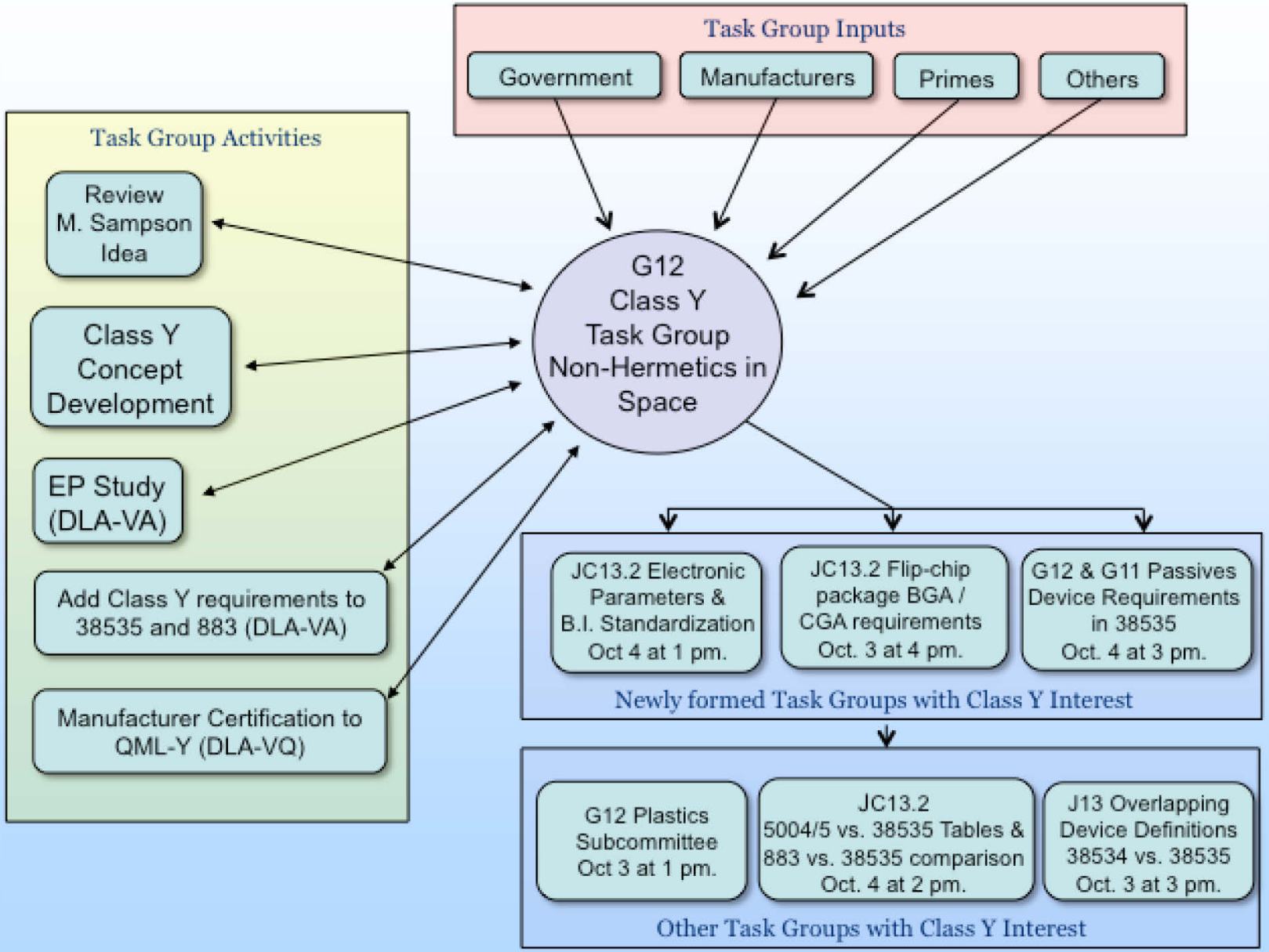
NEPAG = NASA EEE Parts Assurance Group

Class Y – Current Status

- ***DLA-VA conducted Engineering Practice (EP) study on Class Y is in progress.***
  - ****An EP study is the peer review on a very large (world-wide) scale.***

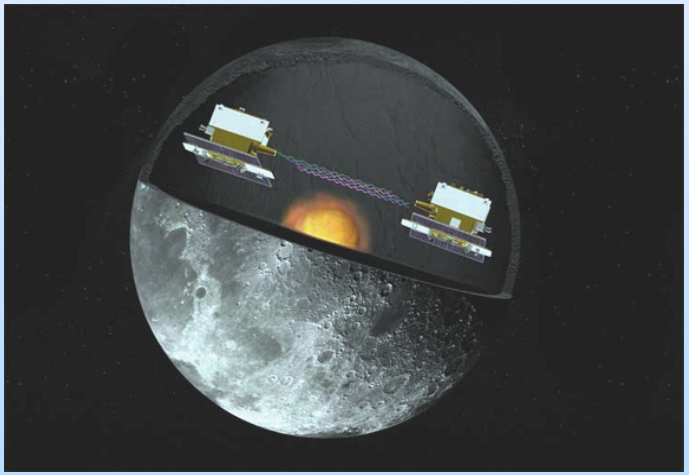
NASA's Mars Science Laboratory Curiosity rover, a mobile robot for investigating Mars' past or present ability to sustain microbial life, is being tested in preparation for launch this fall.

G12 Class Y Effort at a Glance



Road to QML-Y Flight Parts Procurement

- *Major Milestones:*
  - ☑ *G12 approval of TG charter*
  - ☑ *G-12 Class Y Task Group to develop requirements*
  - ☑ *G12 approval for DLA-VA to commence EP study*
  - ☑ *DLA-VA to begin EP study*
  - ☐ *Conclude EP Study*
  - ☐ *DLA-VA to add Class Y requirements into 38535 and 883*
  - ☐ *DLA-VQ to audit suppliers to Class Y requirements*
  - *Users to procure QML-Y flight parts from certified suppliers*

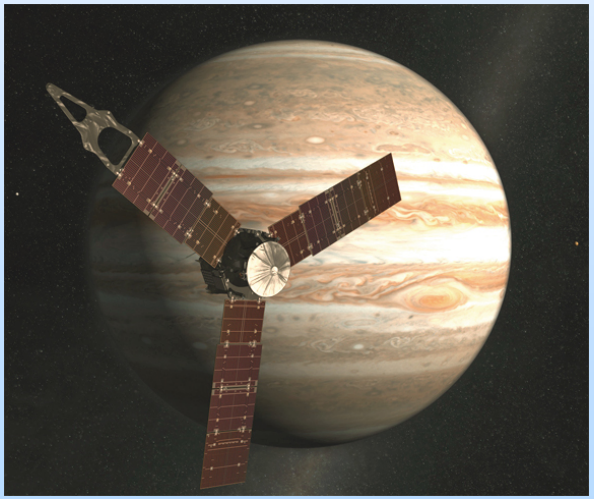


Gravity Recovery and Interior Laboratory (GRAIL) mission, using twin spacecraft flying in formation to investigate the moon's gravity field, a possible inner core and how Earth and other rocky planets formed, launches in late 2011.

The Team

- *The Team members are:*
  - *Muhammad Akbar, DLA-VA*
  - *Larry Harzstark, Aerospace*
  - *David Sunderland, Boeing*
  - *Shri Agarwal, NASA/JPL*
  - *Tom Wilson, NASA/JPL*

- *Team resources include:*
  - *Mike Sampson, NASA/GSFC*
  - *Mark Porter, G12*
  - *Brent Rhoton, JC13*
  - *Anduin Touw, G12*
  - *Mike Adams, DLA-VQ*
  - *Rob Heber, DLA-VA*
  - *Tom Hess, DLA-VA*
  - *Charles Saffle, DLA-VA*



Launching 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.

Future Challenges

- **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

Section Y

G-12 Task Group 10-01
(Class Y)
Summary

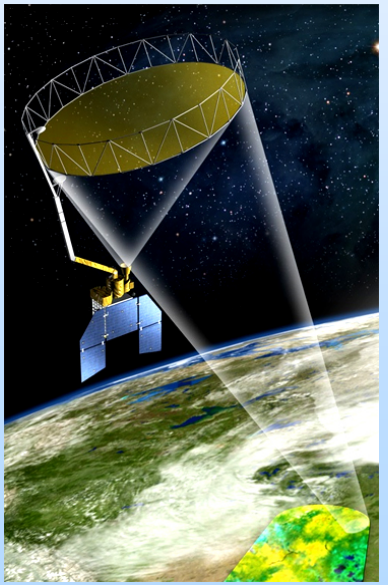
Progress so far

Major milestone achieved:
G12 approved DLA-VA's kickoff of an
Engineering Practice (EP) Study for Class Y.

Background

- ***Back in 2009, there was a big push to bring the Xilinx Viirtex-4 (a non-hermetic part) into the QML system as Class V device. NASA was not in favor as it would have created a massive confusion. Mike Sampson conceived the idea of a new Class Y for non-hermetic space parts to provide QML coverage for Xilinx Virtex-4 and similar devices.***

- ***A new G-12 Task Group, TG 2010-01, was formed in early 2010 to address non-hermetic devices for space. Shri Agarwal was asked to lead the effort.***
  - ***This task was challenging because it:***
  - ***Was far more involved than typical G12 tasks,***
  - ***Required development of a brand new concept,***
  - ***Used system-on-a-chip — one of the most complicated devices,***
  - ***Needed to be simple and easily understood,***
  - ***Possessed sketchy testing and board assembly boundaries, and***
  - ***Was needed to procure a standard QML product as quickly as possible.***

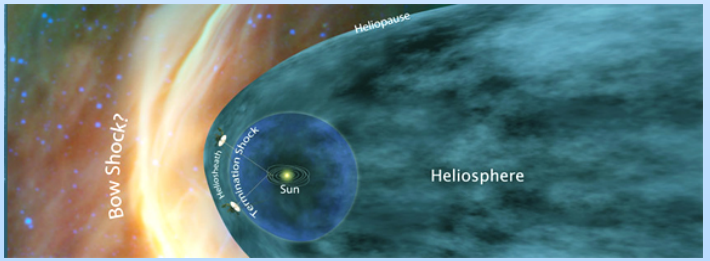


Launching in late 2014, SMAP (Soil Moisture Active Passive) will use a combined radiometer and high-resolution radar to measure surface soil moisture and freeze-thaw state, providing new opportunities for scientific advances and societal benefits.

The SMAP mission has not been formally approved by NASA. The decision to proceed with the mission will not occur until the completion of the National Environmental Policy Act (NEPA) process. Material in this document related to SMAP is for information purposes only.

Why "Class Y"?

- *This effort is an attempt to bring advancements in packaging technology into the QML system.*
- *Advancements in packaging technology, increasing functional density and increasing operating frequency have resulted in single die SoCs (System-on-a-Chip) 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 and have drawn the attention of the space user community*
- *Question: How do we bring V-4 and similar microcircuits into the QML system as space products?*
  - *It can't be Class V because those are non-hermetic devices*
  - *Our intent is to put V-4 like products for space users in a new category: "Class Y". Section 3 explains electronic packaging, why it's needed and builds the case for Class Y.*
  - *A year ago, G-12 opened a Task Group to develop Class Y (details on next slide)*
- *What if we dropped the Class Y effort?*
  - *It would be a big loss for the space community and the QML program at large because the industry would be limited to ordering via Source Control Drawings (SCDs), which is counterproductive to Mission Assurance, prevents standardization, and is expensive.*



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.

G12 Class Y Task Group Summary

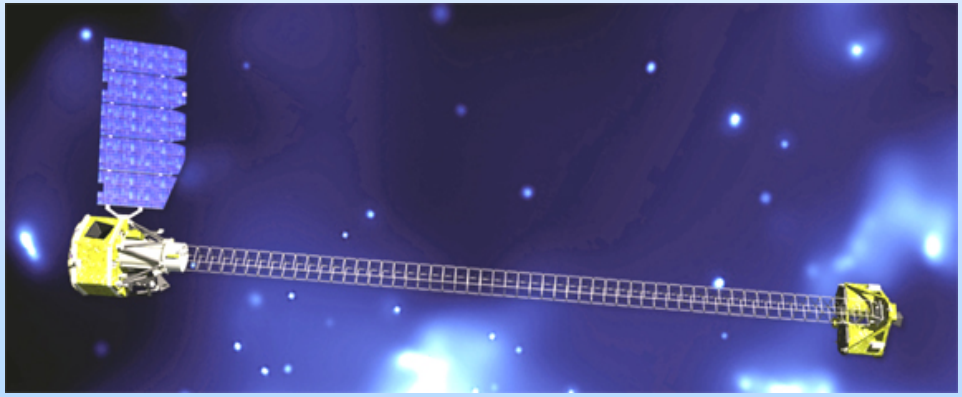
- *G-12 Task Group formed in Jan.'10 to develop screening/qualification requirements for non-hermetics for Space (TG2010-01).*
- *The TG's work so far may be summarized as follows:*
  - *Each of the meetings was well attended*
  - *As soon as the TG was formed, users were enthusiastic and eager to know when they could procure QML-Y flight parts?* *See slide 5 on road to procurement.*
  - *A questionnaire was sent to a targeted group of users, manufacturers and others (There are about 150 names on the Class Y distribution list). The major inputs were:*
    - *Class Y should cover those items that are ceramic flip-chip non-hermetic construction that have passed the requirements of Appendix B. The broader issue of organic based substrates would be addressed in the next phase of this work.*
    - *Some respondents asked why should space community even allow use of non-hermetic parts. (Although the feasibility of a hermetic ceramic package with under-fill flip-chip die has been demonstrated, there are sealing process, board level, and other concerns. There are no current development programs as there is no user interest.)*
    - *Add the word "hermetic" to the definitions of QML-Q and QML-V classes in 38535.*
    - *NASA does not endorse attaching the description "near hermetic" to Class Y. (How do you quantify "near-hermetic": it could be 10% or 99% hermetic, or less than half, or…?). Both DLA-VA and DLA–VQ support NASA position.*

G12 Class Y Task Group Summary (Contd.)

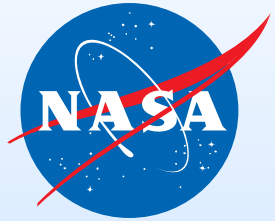
- *TG meetings summary (cont'd):*
  - *Boeing proposed "simplified approach" was adopted:*
    - *Add paragraph to existing 38535 Appendix B stating differences for class Y (most remains same as Class V). One key element is for the manufacturers to submit a Packaging Integration Demonstration Test Plan (PIDTP) to QA for approval. This plan must address issues unique to non-hermetic construction and materials, such as potential materials degradation, interconnect reliability, thermal management, resistance to processing stresses, thermo-mechanical stresses, shelf life, etc. The PIDTP plan shall be approved by QA after consultation with the space community.*
    - *Separate issues related to non-hermeticity from those related to solder terminations (see below).*
    - *Provide markups to other affected documents.*
  - *9 manufacturers have so far expressed interest in offering Class Y products (Xilinx, Actel, Intersil, Aeroflex, BAE, Honeywell, TI, e2v, 3D Plus).*
  - *Government customers and contractors have provided statements of support.*
  - *DLA Land and Maritime – VA (M. Akbar) was added to the team.*
  - *Comment from G12 management: The group may be surprised at how quickly this is moving. Most of the time, documents take over a year to get a full draft. You are far ahead of schedule. People just may not realize that this is out of the conceptual stage and into the writing stage.*

G12 Class Y Task Group Current Status (Contd.)

- *The Team requested G12 approval for DLA Land and Maritime - VA to conduct an Engineering Practice (EP) study using the detailed requirement input the Task Group has developed (Sections 1 & 2 attached). This request was approved by G12.*
- *The Team's request for clear approval of Task Group charter was also approved by G12. The charter statement reads:*
  - *"This task group will develop requirements, including qualification and screening standards, for non-hermetic, ceramic-based microcircuits suitable for space applications. Initial effort will be focused on support for devices using flip-chip ceramic column grid array packaging, with resulting requirements to be submitted as a proposal for consideration to DLA Land and Maritime."*



NuSTAR (Nuclear Spectroscopic Telescope Array) will be the first focusing high energy X-ray mission, opening up the hard X-ray sky for sensitive study. NuSTAR will search for black holes, map supernova explosions, and study the most extreme active galaxies.



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