Reliability & Quality Assurance of EEE Components.

And

Radiation Hardness Assurance of Components

Dr. SV Sharma,

Head Components Division, ISAC

Presentation Overview

Part 1

1. Introduction To High Rel EEE Components
2. Space Environment
3. EEE Components Management
4. Quality Level Of EEE Components Used in ISRO Satellite Application – Current Practice
5. Preferred Parts Lists For EEE Components
6. Current Trends Challenges in Components
7. COTS & PEMs
8. Possible Approach for Future Satellite Programs
9. Space Radiation Environment
10. Summary and Conclusion

Part 2 - Overview Radiation Studies

- Constituents of Space Radiation Environment
  - Galactic Cosmic Ray Ions
  - Solar Particle Events
  - Trapped – Van Allen Belts
  - South Atlantic Anomaly
  - Summary of Radiation Environment and Models
- Radiation Effects on Electronic Components
  - Total Ionsing Dose (TID) effect on MOS, BJTs
  - Enhanced Low Dose Rate Sensitivity (ELDRS) Effect
  - Total Non-Ionsing Dose (TNID) effect
  - Single Event Effects (SEE)
- Radiation Effects on Submicron Technology
- Summary & Conclusion

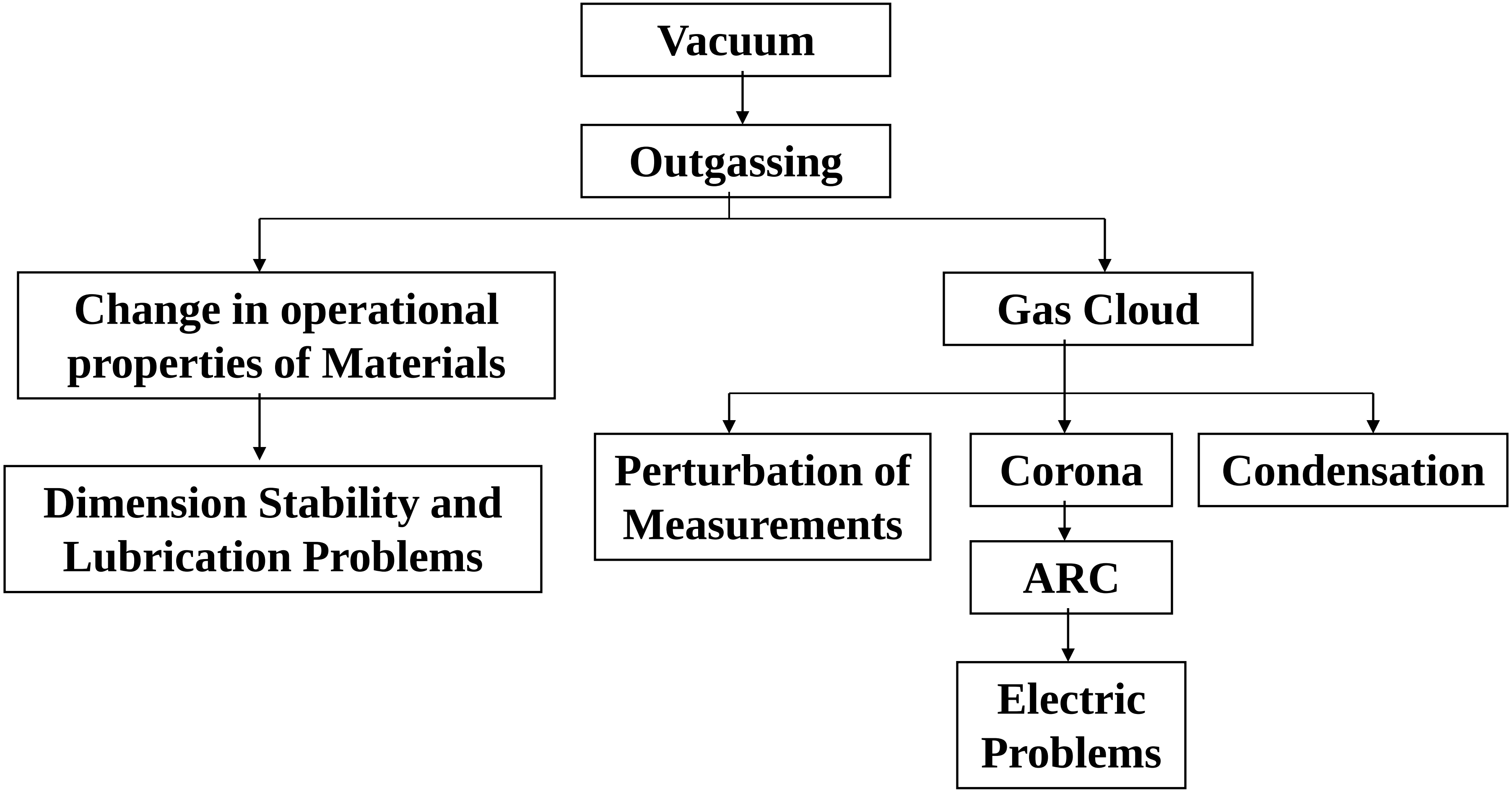
Introduction

- What are Hi-Rel Components?
  - Covered by Detailed MIL/ESA/NASA specifications.
  - Known Performance (Reliability)
  - Controlled/monitored sources
  - Traceability Requirements
  - Change notification System/Alert Systems
  - Interchangeability-eg.SMD numbers
  - Heritage in Satellite Application
- Space Application Considerations:
  - Functional/Application
  - Mission Reliability Goals
  - Heritage
  - Basic Quality Level
  - Quality Assurance Tests
  - Space Environment

Space Environment

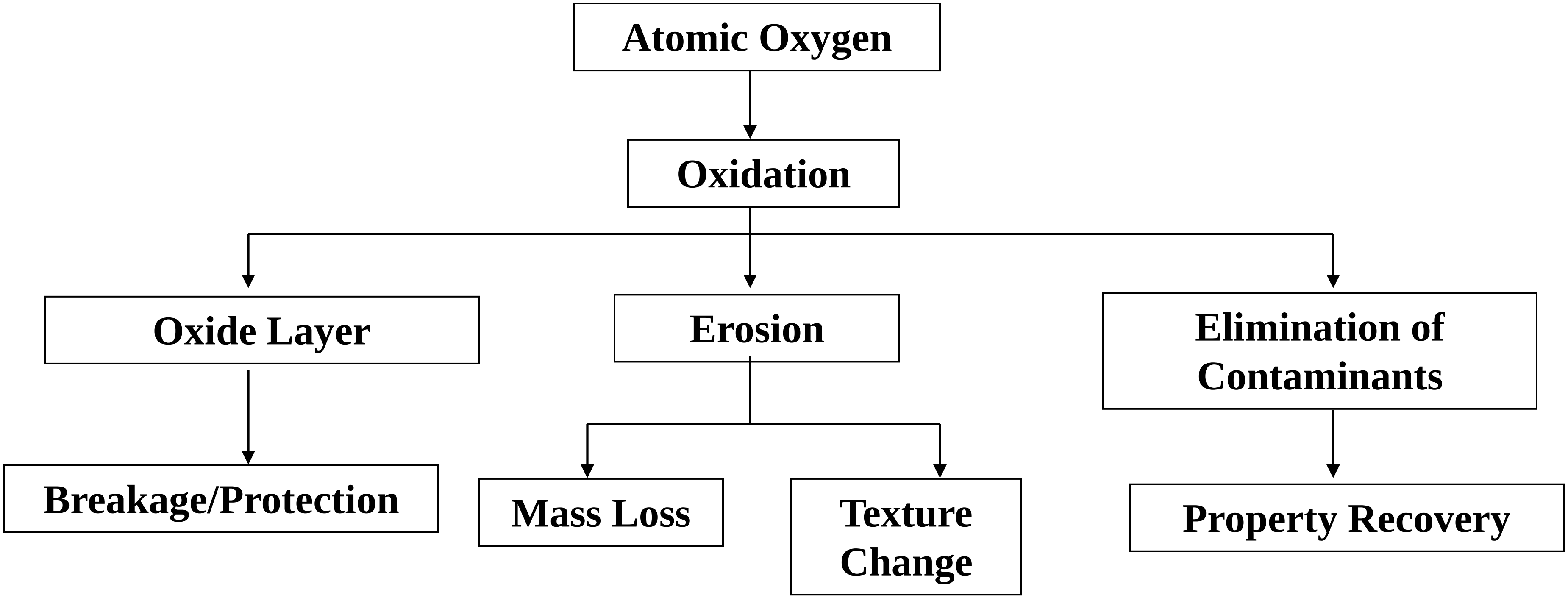
- Vacuum Environment
- The Neutral Environment
- Plasma Environment
- Micrometeroids / Orbital Debris Environment
- Micro-Gravity
- Thermal Environment
- Geomagnetic Field
- Space Radiation Environment

Vacuum Environment



Thermal Issue Separately addressed

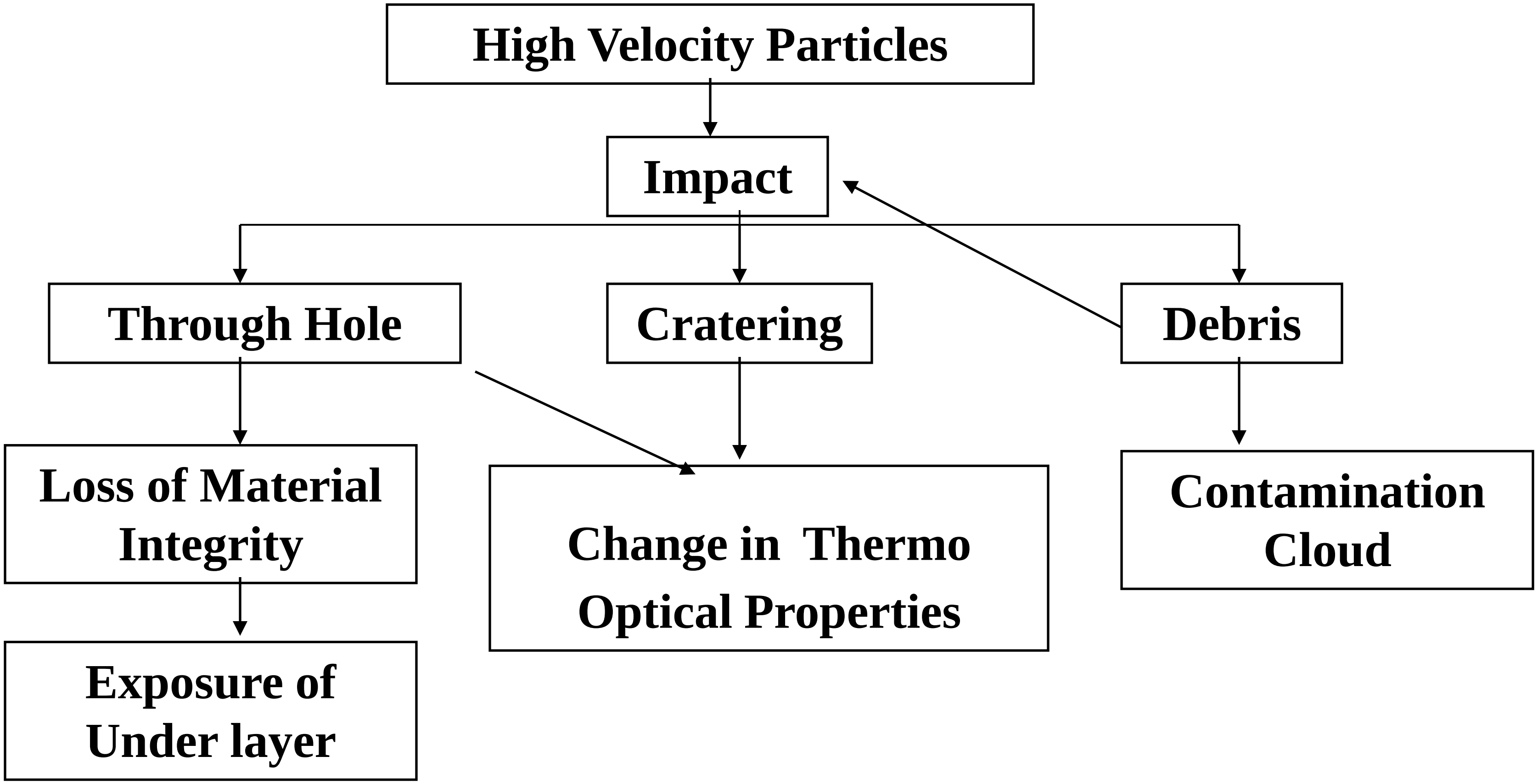
Neutral Environment



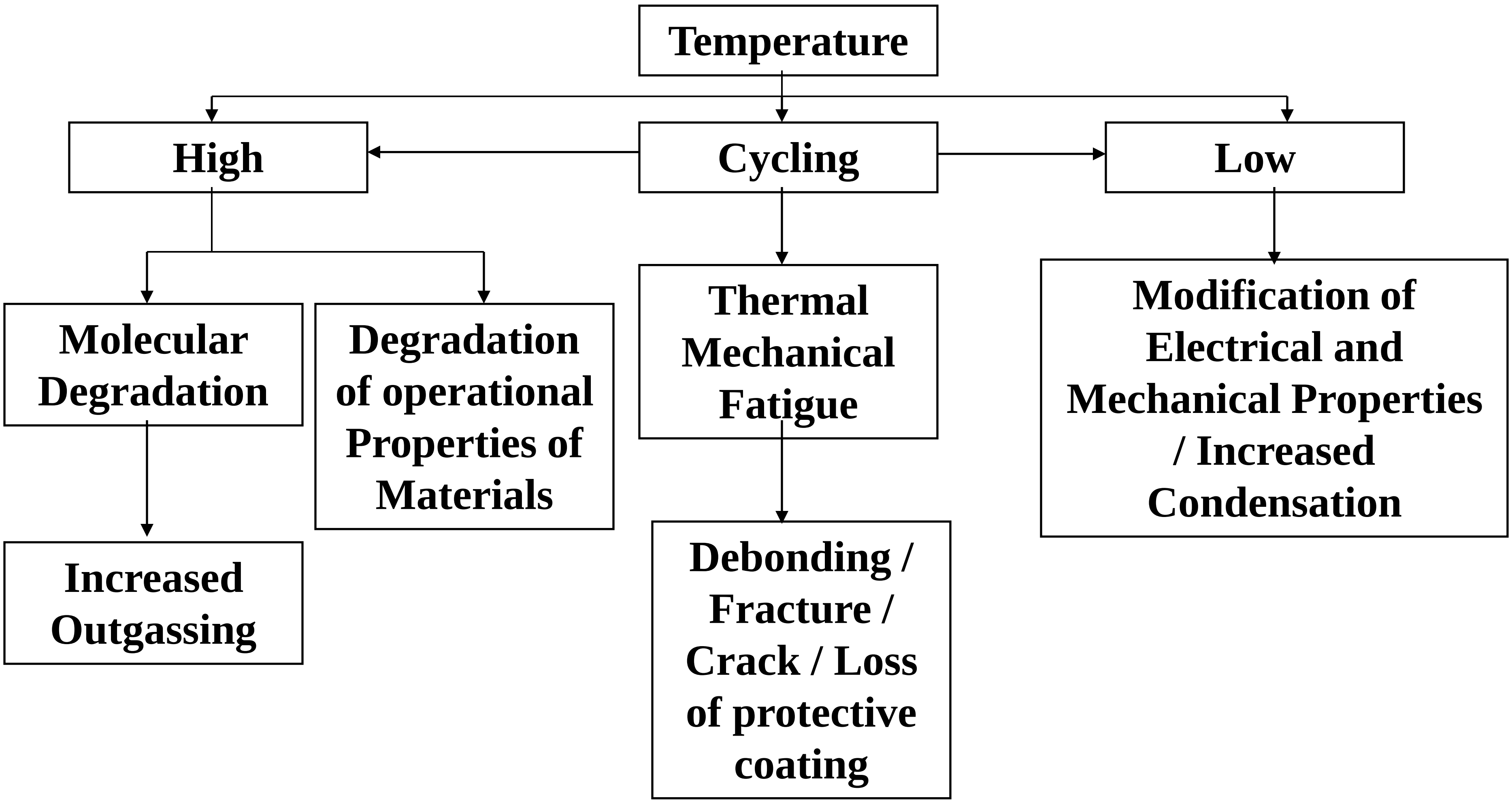
Plasma Environment

- Spacecraft surface charging and deep dielectric charging result in discharges that can cause background, interference on instruments and detectors, biasing of instrument readings, physical damage to materials, upsets and physical damage to electronics, increased current collection, re-attraction of contaminants, and ion sputtering which leads to acceleration of erosion of materials.
- Plasmas are responsible for surface charging; particularly in planetary radiation belts where storm induced fluctuations occur.
- Deep dielectric charging results from higher energy electrons penetrating and collecting in non-conducting materials until the material's dielectric breakdown is reached and a discharge occurs.

Micrometeroids / Orbital Debris



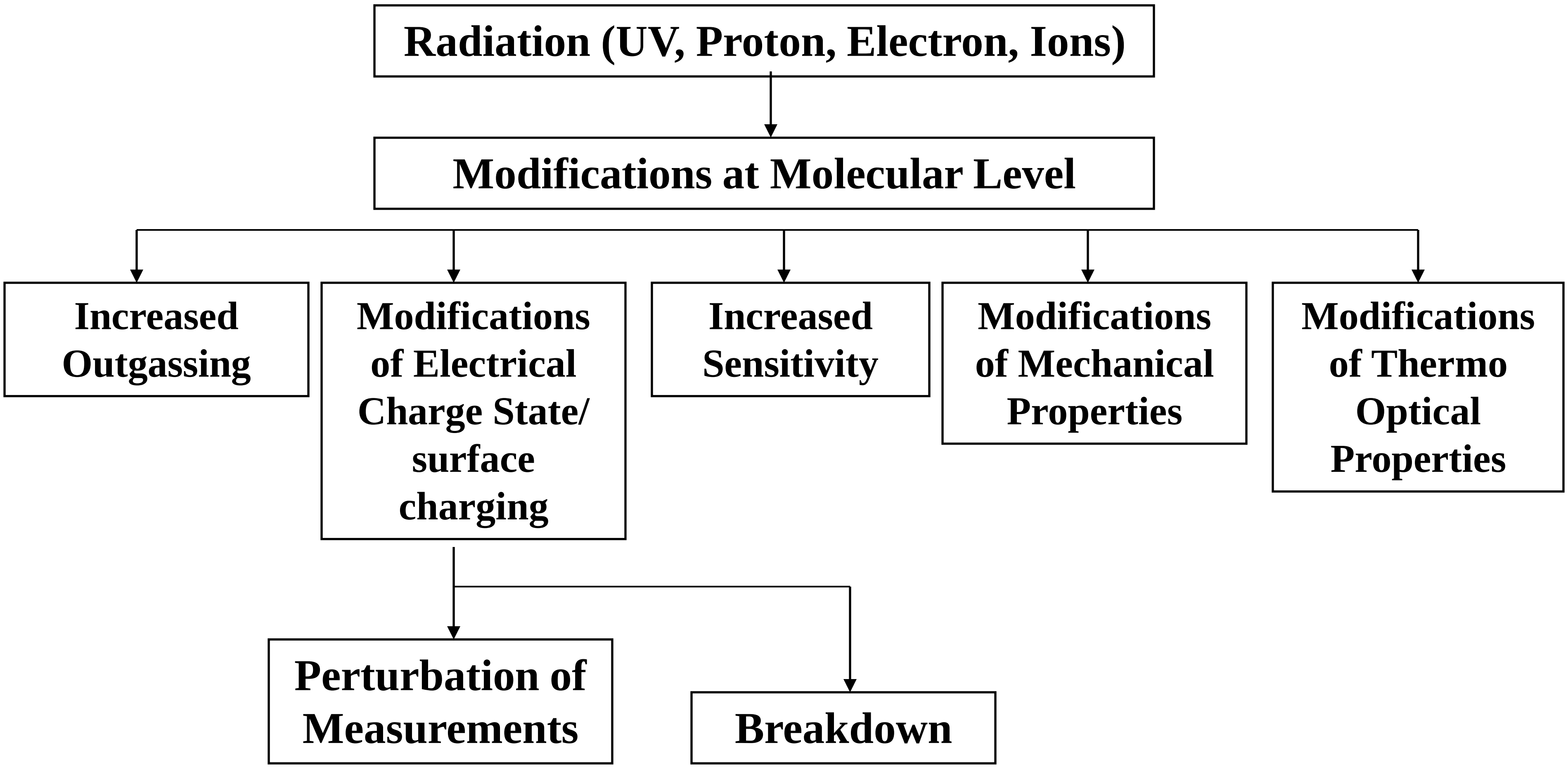
Thermal Environment



Geomagnetic Field

- Due to dipole field geometry, the magnetic field strength is lowest over the southern Atlantic Ocean, which leads to a higher concentration of trapped radiation in this region.
- It is in the vicinity of the South Atlantic Ocean that a spacecraft may encounter electronics “upsets” and instrument interference (South Atlantic Anomaly).
- An accurate depiction of the geomagnetic field is needed to properly size magnetic torquers used in guidance, navigation, and control (GN&C) systems.
- Disturbances in the geomagnetic field lasting one or more days are called geomagnetic storms. When a geomagnetic storm occurs, large numbers of charged particles are dumped from the magnetosphere into the atmosphere.

Radiation Environment



EEE Parts Management

EEE Part Management

- Procurement Support – Various Stages Pre, During and Post
- Standardisation of Procurement Specifications
- Activities to meet the project Requirement
  - Incoming Inspection
  - Relifing
  - Screening
  - LAT /VOQ testing
  - Up screening of nonstandard parts
  - Lot qualification of Non PPL Parts
- NCR management
- Radiation Hardness Assurance
- Additional Testing and Simulation /Analysis
- Inventory Management
- Productionisation Support
- Application Guidelines /Alert management

EEE Part Management

- The Selection and application of EEE parts for satellite application is to be critically reviewed considering the various space environment conditions.
- All aspects of reliability and relevant known failure modes and mechanisms should be addressed prior to the insertion of the component in the application.
- The environmental, reliability and operational challenges present a challenge to the application of commercially available technology of parts and materials.
- The advanced technology satellites for parts and materials are more stringent than most other ongoing projects.
- Space radiation effects are a major driver of acceptability of a product for reliable space application. Radiation should be taken into account in the early phases of a program development
- All aspects of reliability and relevant known failure modes and mechanisms should be addressed prior to the insertion of the component in the application.

General Parts Program Requirements

- Part selection and standardization requirements
  - Approved Parts and Materials List
- Parts Quality level
  - NASA GSFC EEE-INST-002, level 1
  - QML/QPL Class S, V for ICs
  - QML/QPL Class K for hybrids
  - QPL JANS for diodes and transistors
  - Established reliability Failure Rate Level T, S for passives
- DPA (Destructive Physical Analysis) and RGA (Residual Gas Analysis) for Non-Std parts
- PIND (Particle Impact Noise Detection) for cavity devices
- Surge current testing for solid tantalum capacitors

General Quality Level of Components

<table>
<tr><th>Sl. No</th><th>Device types</th><th>Quality Levels</th><th>Screening</th><th>VOQ Tests</th></tr>
<tr><td>1.</td><td>Integrated Circuits
-Linear
-Digital</td><td>• QML V Qualified/Processed of MIL-PRF-38535
• Class K Qualified/ Processed of MIL- PRF- 38534
• Class S Qualified / Processed of MIL-M-38510
• ESCC 5000 Qualified / Processed</td><td rowspan="2">100%
screening
Tests as per
Applicable
MIL/ESCC
Specifications
including 240
/320/1000 Hrs
Burn in

No deviations Allowed</td><td rowspan="2">– LAT2 for Processed

– LAT 3 For Qualified

– Generic Group A,B,C,D& E for Qualified

– In line Group A,B,C,D & E for Processed

–DPA Test</td></tr>
<tr><td>2.</td><td>Discrete Devices
-Diodes
-Transistors
-FETS
-MOSFETS
-Opto couplers</td><td>• JAN S Qualified/ Processed of MIL- PRF-19500
•ESCC 5000 Qualified / Processed</td></tr>
</table>

General Quality Level of Components Contd...

Sl. No	Device types	Quality Levels	Screening	VOQ Tests
3.	**Passive components** - Resistors - capacitors - Cores - Thermistors /PRTs - Heaters - Fuses	•Established Reliability **levels T, S or R** for resistors & capacitors. • Other types are in accordance with Mil / GSFC / ESCC / ISRO generic specifications	100% screening Tests as per Applicable NASA PPL-21 including Burn-in	Group B, C, D inspections
4.	**RF Components** - Discrete devices - Clock oscillators - Passive components - MMICs	•**JAN S Qualified/ Processed** of MIL-PRF-19500 • **ESCC 5000 Qualified / Processed** • **MIL-PRF-55310 class S Qualified /processed** for oscillators • Other types are processed in accordance with Mil / ESCC generic specifications or SCD of mfr.	Screening as per applicable specs No deviation allowed	Life Test, DPA, Lot specific group tests

General Quality Level of Components Contd...

S.No	Device types	Quality Levels	Screening Level	VOQ Tests
5.	**Electro Mechanical Components** - Relays - Connectors	Qualified To • ESCC3601 • ESCC 3602 • GSFC S311-P-745 • ESCC 3401 • GSFC S311-P-4	100% screening Tests as per Applicable ESCC /GSFC Specifications including Operational Reliability Test(Miss Test) No deviations Allowed Final Production Tests	– LAT 2 for Processed – LAT 3 for Qualified – MTUV Test – DPA Test – FCSI –Fabrication Related Tests

Preferred Parts List - PPL

Preferred Parts List - PPL

Parts Listed based on Quality level as per

- NASA GSFC EEE-INST-002, level 1
- QML/QPL Class S, V for ICs
- QML/QPL Class K for hybrids
- QPL JANS for diodes and transistors
- Established reliability Failure Rate Level T, S for passive
- Indegenous Parts
- ISAC heritage and Custom Parts

ISAC PPLs provide information such as

- ISAC PPLs provide information such as
- Basic part number,
- MIL / ESA/NASA/GSFC, part number
- Quality level
- Decoding of part
- Package details
- Mounting Details
- Lead Finish
- Sources of Supply/ Manufacturer list etc…

Details of PPL - released

Preferred Parts Lists – 8 volumes

1. Digital Microcircuits
2. Linear Microcircuits
3. Discrete Semiconductor Devices
4. Relays, Fuses & Fusistors
5. Connectors
6. Resistors
7. Capacitors
8. RF Components

Procurement Specifications – 4 Volumes

1. **Procurement Specifications For Active Components**
2. **Procurement Specifications For Electromechanical Components**
3. **Procurement Specifications For Passive Components**
4. **Procurement Specifications for All HMC dice**

1. Preferred Parts List – RF PPL

First Time generated

Exhaustive

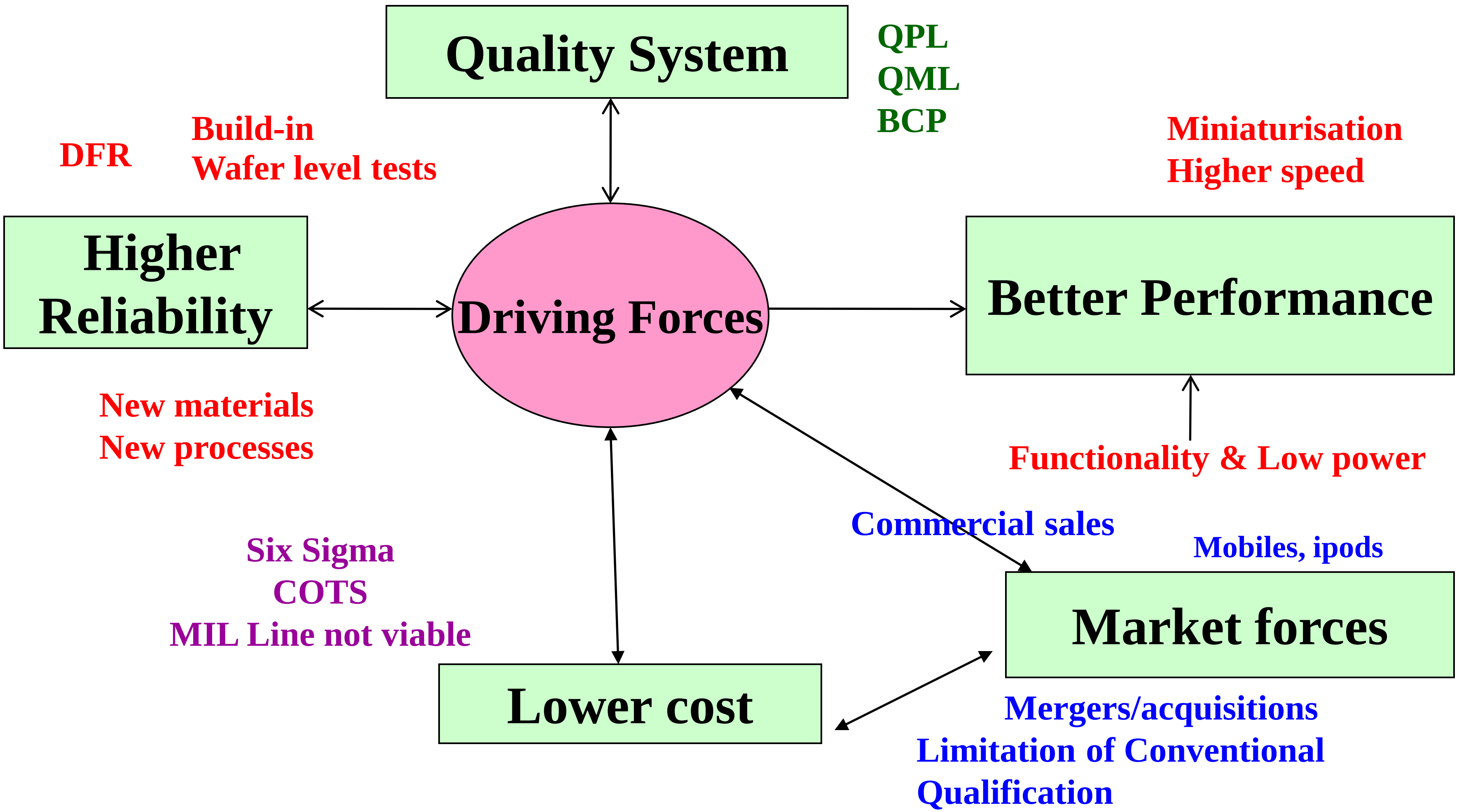
Includes TCXO, VCXO, Oscillators, Isolators, Filters Attenuator, SRDs, RF Transistors, Circulators, switches etc

Features of RF PPL

- **RF Components can be divided into 3 parts based on component type viz. Active devices, Passive devices, RF Cable &Assemblies**
- **Many RF components are non standard parts. Non Standard parts: Either processed to MIL/ESCC Spec or based on Manufacturers Internal Hi-rel.**
- **Components listed in the PPL are known by technology and are potential for usage in flight standard hard ware of LEO & GEO missions.**
- **Most of the connectors, terminations & attenuators are manufacturer's standard parts having heritage in our space programme.**
- **Diminishing parts along with equivalent alternate parts are also included.**
- **The annexure consists of package dimensional drawing.**

Current Trends in EEE Industry and Associated Challenges

Current Trends



Major Reliability Challenges for Space Applications

A. Changes in Quality System – Product Assurance

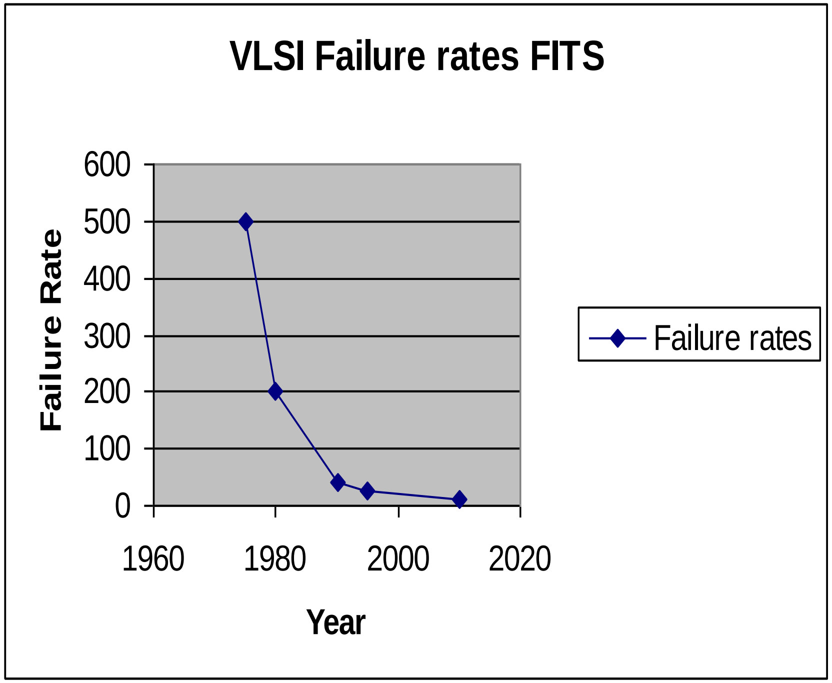
B. Technology Related

C. Miniaturizations- Package Reliability

D. Market Forces

1a. Product Assurance: Current Trends…Contd

- QPL to QML to COTS
- MIL-HDBK-217F Vs Physics of Failure (POF)
- Reliability goal Vs Time
- Evolution of Advanced Technology Devices-ASICs, FPGAS, MEMs, MMICs..
- Optimized Burn-in
- CRH technology



Considering the density of 10E8 Transistors life time of single element Approaches age of the universe

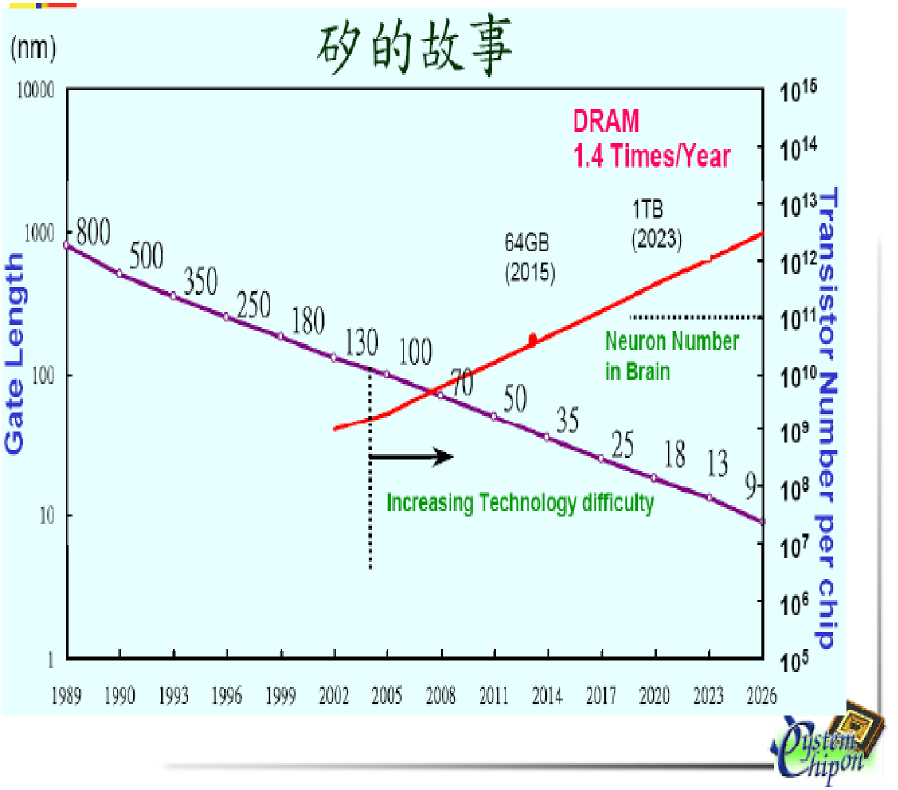
1b. Challenges - Product Assurance

- QPL vs QML
  - TRB Approach
  - Limited Life Test
  - No Independent Precap Visual Inspection
- Usage of parts that may not have space heritage
- MIL HDBK 217F no more updated and maintained; Also POF approach has its limitation
- Screening and qualification Issues for New devices
  - Long Term Reliability Considerations: Necessitates Qualification and Life Tests
  - Understanding new failure modes/mechanisms if any
  - Traceability and Documentation
  - Process Qualification and Repeatability
  - Outgassing property of the materials
  - Performance in Thermovacuum conditions
  - Vibration and Shock loads during launch and other operations
  - Radiation Hardness Assurance

Current Trends

2a.Advancement In Technology: "Faster, cheaper, better" approach

- Line width Shrinkage
- More number of transistors
- Reduced Gate Oxide thickness
- Introduction of new materials
- Package trends
  - Multi-Chip Modules (MCM)/ System-in-Package (SIP)/
  - System-on-Package (SOP) / System-On-Chip (SOC)

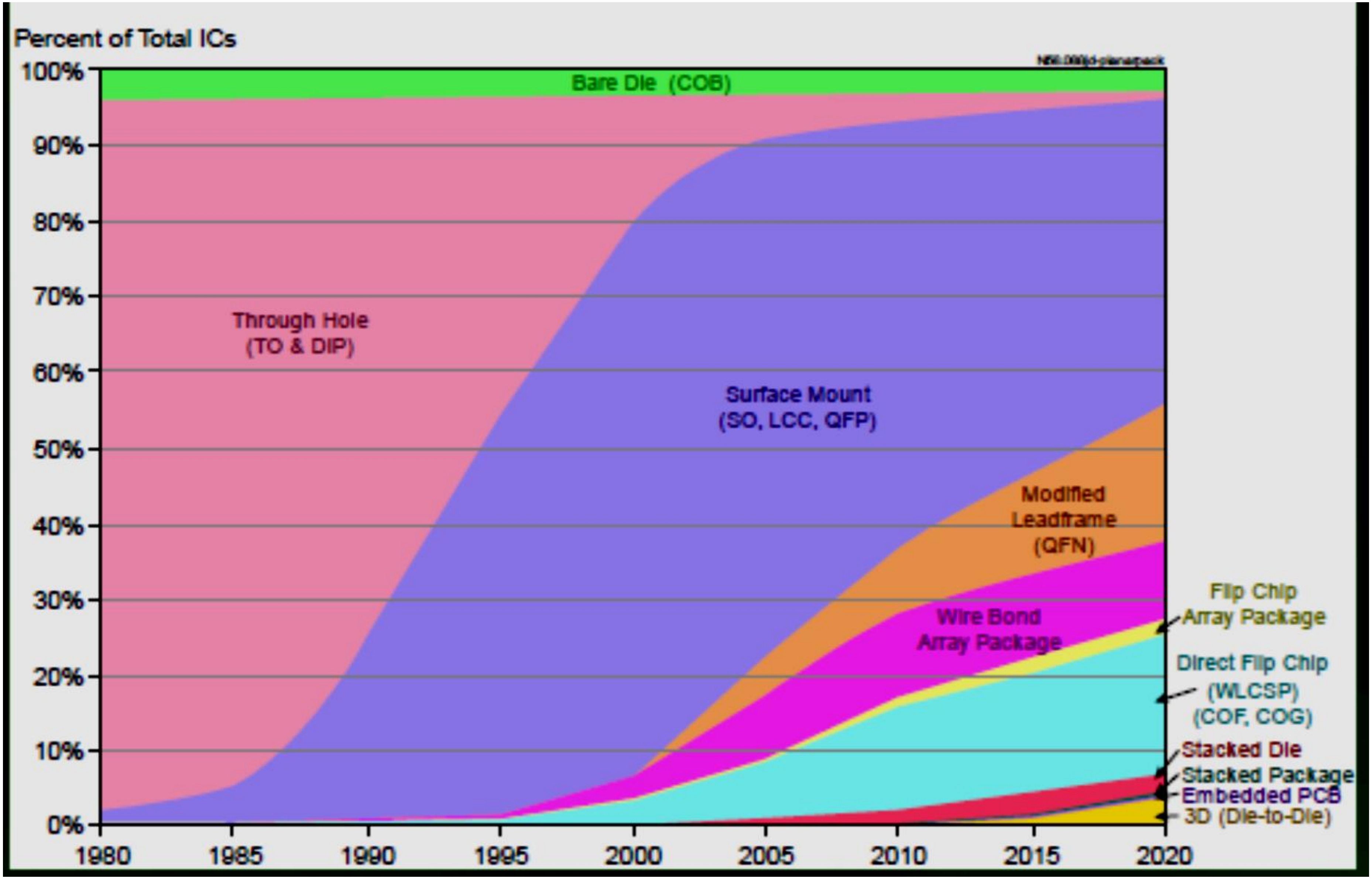


2b. Advancement In Technology - Challenges

- Semiconductor Reliability: Wear Out failure Issues.
  - Electro migration (EM)
  - Time Dependent Dielectric Break down (TDDB)
  - Hot Electron effects
  - Stress induced migration (SM)
  - Latent ESD etc.
  - Radiation Related

- Test and Evaluation:
  - DFT
  - Fault Coverage
  - Burn-In
  - Test Complexity

3 .Miniaturisation- Package Reliability - Trends



– Thermal management- Inspection

Current Trends…Contd

4a. Market Forces

– Mergers/Acquisitions

– Limitation of Conventional Qualification

– MIL Line Economically not viable

– Fab less Vendor

– Commercial Radhard Foundries

– ROHS compliances and other issues

– COTS & PEMs

4b. Market Forces: Challenges for Space Applications

Market Trends	**Issues**	**Possible Approach**
COTs & PEMs	Reliability Tracebility	Additional & application specific Test
Short Product life cycle	Qualification Time & Obsolescence	Optimized Qualification Plan
Closure of MIL Line	Non availability of SMD parts	-
Counterfeit Parts	Ensuring the Quality & Source of Parts	Detailed Procurement Specification Incoming Inspection

Current Trends…Contd

4c. Trends Towards Usage of Cots Driven By:

- Cost
- Availability
- Market Forces
- Performance
- Low cost solutions
- Volume Production
- Hi-rel plastic development

Commercial Off-The-Shelf (COTS)

- Implementation of commercially available technologies for traditionally customized applications
- Examples:
  - Military
  - Industrial
  - Space
- Applies to Hardware and/or Software

The Material We Work With:

- **Convetional Old style --- Hi-Rel: ”manufacturing lot” controls, defined performance with strong protections against fraud, notification of changes, ALERTS, qual and screening programs.**

- **New style --- commercial PEMs: no lot controls, vaguely defined performance with no recourse from "bad data", no notification of changes, no ALERTS (better not try it!), mysteries about “qual”ing and about screening.**

- **We need several kinds of special care to incorporate commercial PEMs into spacecraft. Detailing some of these is the purpose of this talk.**

Why Use Commercial PEMs?

- **Mainly availability!** Hi-Rel parts are less than 0.5% of the market => many manufacturers have switched to making only commercial PEMs. Increasingly, we cannot find Hi-Rel parts.
- High performance in small low-power packages.
- Cost is almost never a driver. Commercial PEMs cost more per part than the Hi-Rel devices do, after qual and screening.

What Are The COTS Problems When Upgrading/Upscreening

- **Little or no support from the Manufacturer**
- **Commercial Fab Processes**
  - Cost reduction is constant-so are changes
  - Neither Process nor Design Change is communicated to users
  - Constantly shrinking geometry
  - What you get today will not be the same tomorrow
  - Die - will element eval qualify the parts**?**
- **Upscreening**
  - Is the performance of the part completely tested? How do you know?
  - Non-uniformity – lot to lot and fab to fab variations
  - What will be the long term effect of using the part beyond it's design range?

COTS PEMs Dangers (Part 1)

- The key idea: commercial PEMs are being carefully aimed at a precisely defined market. And *it is not the spacecraft market*.
- Myth: The lowest possible piece-cost / Highest initial performance.
- What is sacrificed for Myth: Reliability extending past one year (or a few years).
- ESD hardness / EOS robustness.
- Not even on the table: Radiation hardness / Operation in a vacuum.

COTS PEMs Dangers (Part 2)

High performance and low-cost - Attempt

- Crowding circuits => "hot electron"degradations.
- Thinning traces => electromigration-induced breaking of traces giving electrical "opens".
- Thinning dielectrics => dielectric breakdown.
- Passivation layers are being omitted.
- All the above can lead to "wear-out": a failure probability that stays low until after a threshold time, and then rapidly increases.

COTS PEMs Dangers (Part 3)

- The ESD/EOS guard circuits are gone in some cases.
- The physical sizes of the parts are shrinking profoundly.
- Hence, the capacitance of each pin is decreasing, so that a given amount of charge deposited onto a pin will increase its potential more than used to be the case.
- The dielectric thicknesses are decreasing, along with their breakdown voltages.
- ESD/EOS damage is now affecting many devices.

Myths About COTS for Space

- **Are just as reliable because**
  - They are made on a commercial SPC controlled line
  - Can be upscreened without a problem
  - Automotive Flow will yield parts as good as Hi Rel ones
  - Can be derated and will work fine
- **BUT**
  - SPC will only give control within design parameters
  - Cannot be upscreened indiscriminately
  - Automotive Flow Fallacies-volume vs portfolio
  - Derating & Upscreening have risks that are not always comprehended

What To Do for COTS?

– Work closely with the manufacturers: get data.
– Be vigilant for changes in the parts being supplied: different wafer supplier, different mask, different foundry, different wire bonder, different plastic composition, different encapsulation parameters.
– Check that the flight parts work in their circuits.
– Set aside extra time for the qual and for the screening.
– Ensure alternative choices --- be cautious about committing to a unique part because it is “sweet”.

What To Do For COTS ? Contd…

- Pick the device carefully
- Pick the Manufacturer carefully
- Pick the up-screener carefully
- COTS may be the only path to get the technology you need
  - You have to use COTS parts

BUT

- It is neither cheaper nor better
  - May be better technology
- It may be as good if done correctly
- And it could be faster if not done correctly

COTS FOR SPACE IS NOT CHEAPER!!

Summary & Conclusion – Part1

- R & QA of EEE Components is Presented
- Space environment poses serious challenge in selection and usage of Components
- EEE Components Management is complex and is multi disciplinary
- ISAC had been following conventional method of selection and usage of high rel components. But the trend will change.
- ISAC PPL and Procurement specs documents are very widely referenced documents
- Space industry is on the process of following Market trends driven by large volume products
- QML to QPL to COTS transition is happening and will sustain
- Care is to be taken while introducing the COTS components