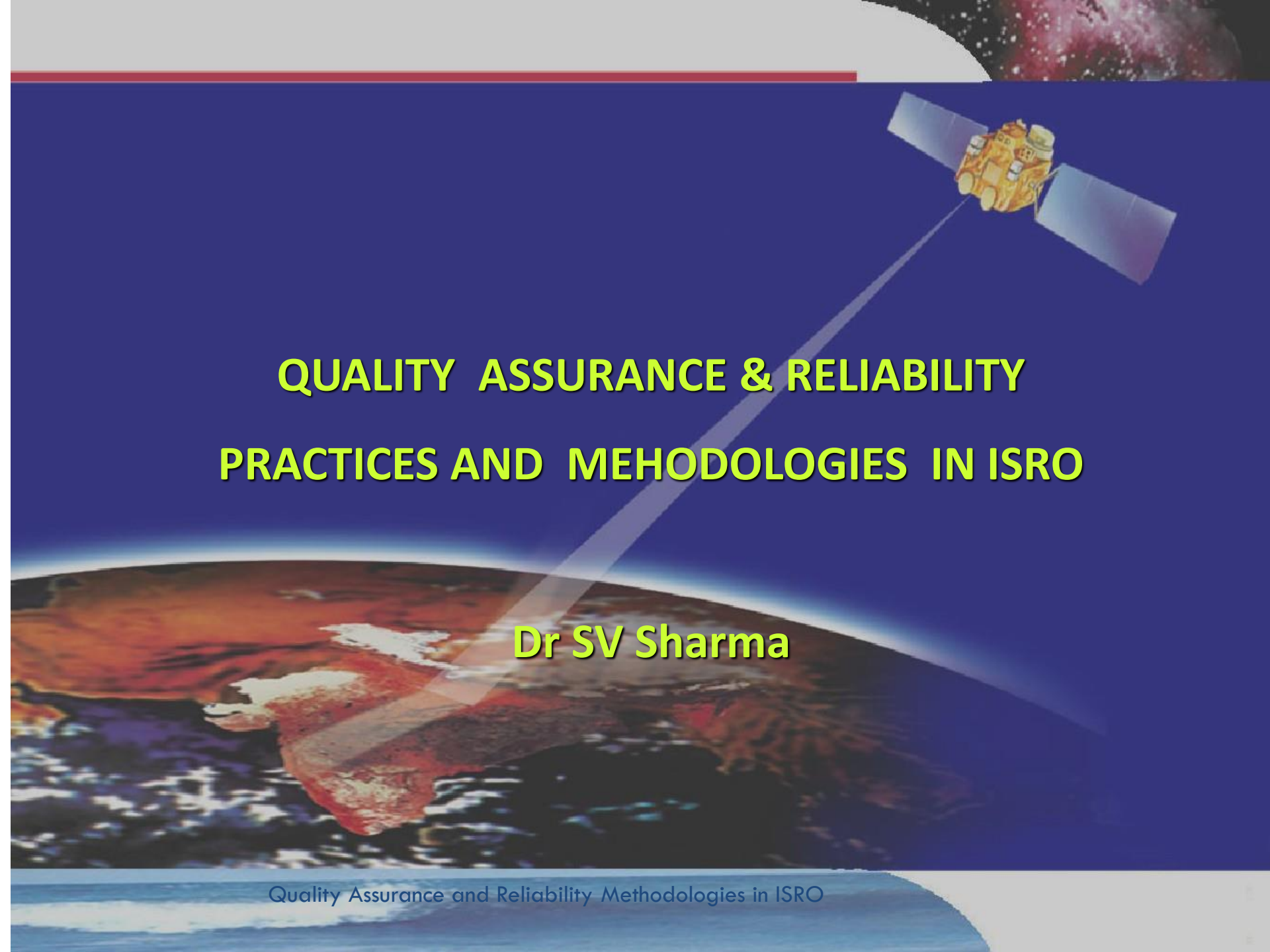


A satellite with two large solar panels is shown in orbit against a deep blue space background. Below the satellite, the curved horizon of the Earth is visible, showing a mix of brown landmasses and blue oceans. A bright, glowing line of light separates the dark space from the Earth's surface. The title text is centered in the upper half of the image.

QUALITY ASSURANCE & RELIABILITY PRACTICES AND MEHODOLOGIES IN ISRO

Dr SV Sharma

Contents

- Introduction
- Quality Management System organization at ISRO
- Quality and Reliability Growth in general – Historic perspective
 - ▣ Space systems and associated intricacies
- Major disciplines of RELIABILITY & QUALITY ASSURANCE
- Reliability growth process – ISRO experience
- Challenges and accomplishments
- Emerging trends
- Conclusion

Four Decades of Indian Space Programme

Applications driven, self-reliant programme
Focus on supporting national development goals

November 21, 1963



41

Launch Vehicle Missions

35

Satellites from other countries

69 + 2

Spacecraft Missions

LAUNCH VEHICLE

SATELLITE

INSAT-3E
28.09.03

KALPANA-1
12.09.02

ARYABHATA
19.04.75

INSAT-3C
24.01.02

INSAT-2E
03.04.99

INSAT-3A
10.04.03

EDUSAT
20.09.04

INSAT-4A
22.12.05

CHANDRAYAAN-1
22.10.08

IRS-1C
28.12.95

IRS-P3
21.03.96

IRS-1D
29.09.97

IRS-P4
26.05.99

TES
22.10.01

RESOURCESAT-1
17.10.03

GSAT-2
08.05.03

CARTOSAT-1
05.05.05

HAMSAT
05.05.05

CARTOSAT-2
10.01.07



APPLICATIONS

MOM
IRNSS-1A 05-11-13
01-07-13 GSAT-7
GSAT-10 30-08-13
29-09-12 INSAT-3D

GSAT-12 26-07-13
15-07-11 SARAL

GSAT-8 25-02-13
21-05-11

HYLAS RISAT-1
26-11-11 26-04-12

W2M MEGHATRO
21-12-08 12-10-11

INSAT-4CR RESO-2
02.09.07 20-04-11

INSAT-4B OCEANSAT-2
12.03.07 23-09-09

**ISRO Quality Organisation
Spacecraft**

**CHAIRMAN
ISRO**

DSRQ

**Director
VSSC**

**Director
SHAR**

**Director
ISAC**

**Director
SAC**

**Director
Gr. Stns.**

SRG

SRG

DD, RCA

SRG

SRG

GD, SRG

GD, ICG

**RAED
(Electrical)**

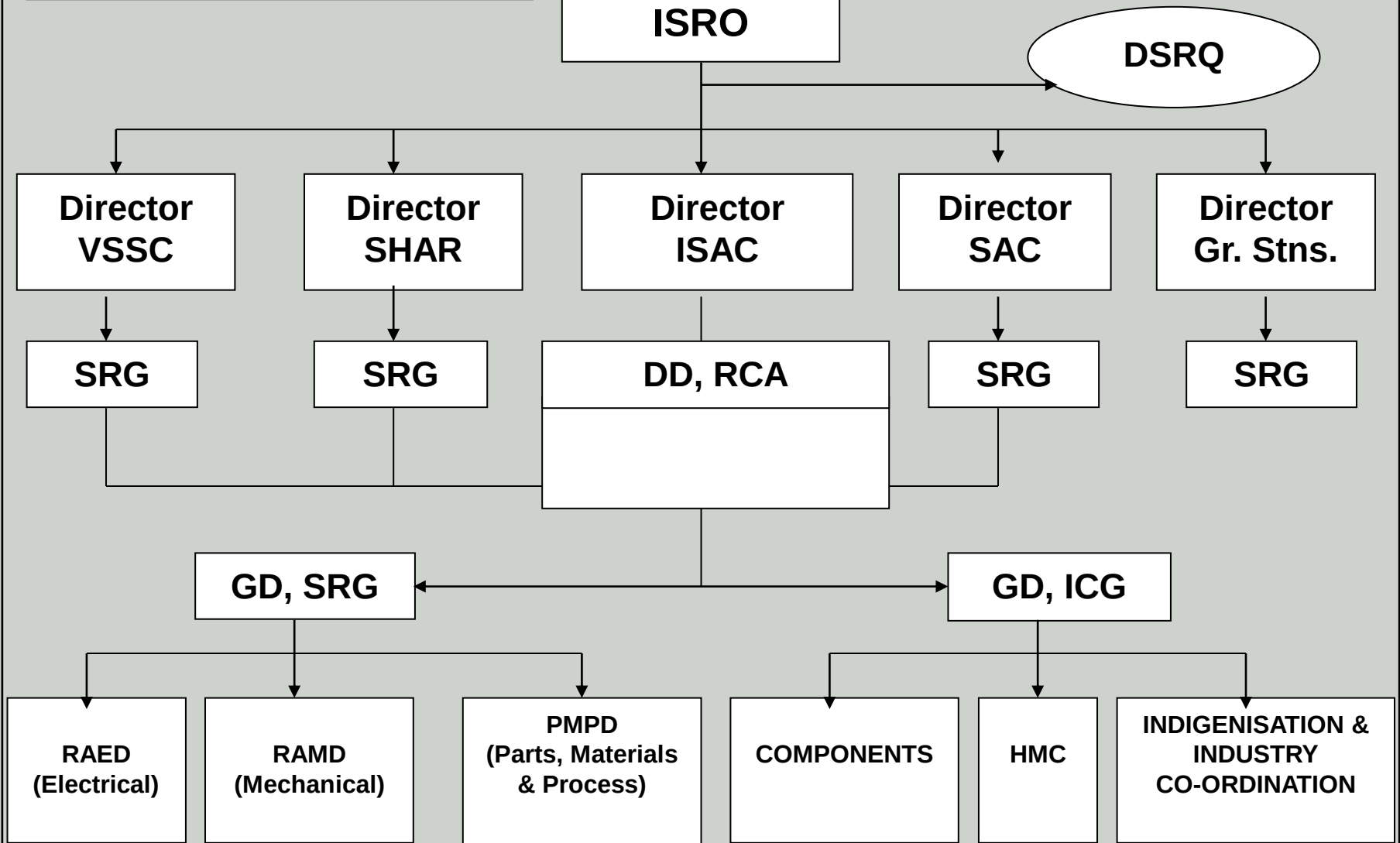
**RAMD
(Mechanical)**

**PMPD
(Parts, Materials
& Process)**

COMPONENTS

HMC

**INDIGENISATION &
INDUSTRY
CO-ORDINATION**



R & QA Organization
Satellite Projects - ISAC

DIRECTOR

Dy. DIRECTOR, RCA

CHAIRMAN, PAB

PROGRAMME DIRECTOR

CHAIRMAN, PMB

PROJECT DIRECTOR

**CONFIGURATION
CONTROL**

OTHER CENTRE DPDs

SUBSYSTEM DPDs

OTHER CENTRE SRG

**DPD
R & QA**

**SAFETY
SYSTEM**

**PM
ELECTRICAL**

**PM
PROCESS**

**PM
MECHANICAL**

**PM
PARTS**

GROUP DIRECTOR, ICG

GROUP DIRECTOR, SRG

**HEAD
PMPD**

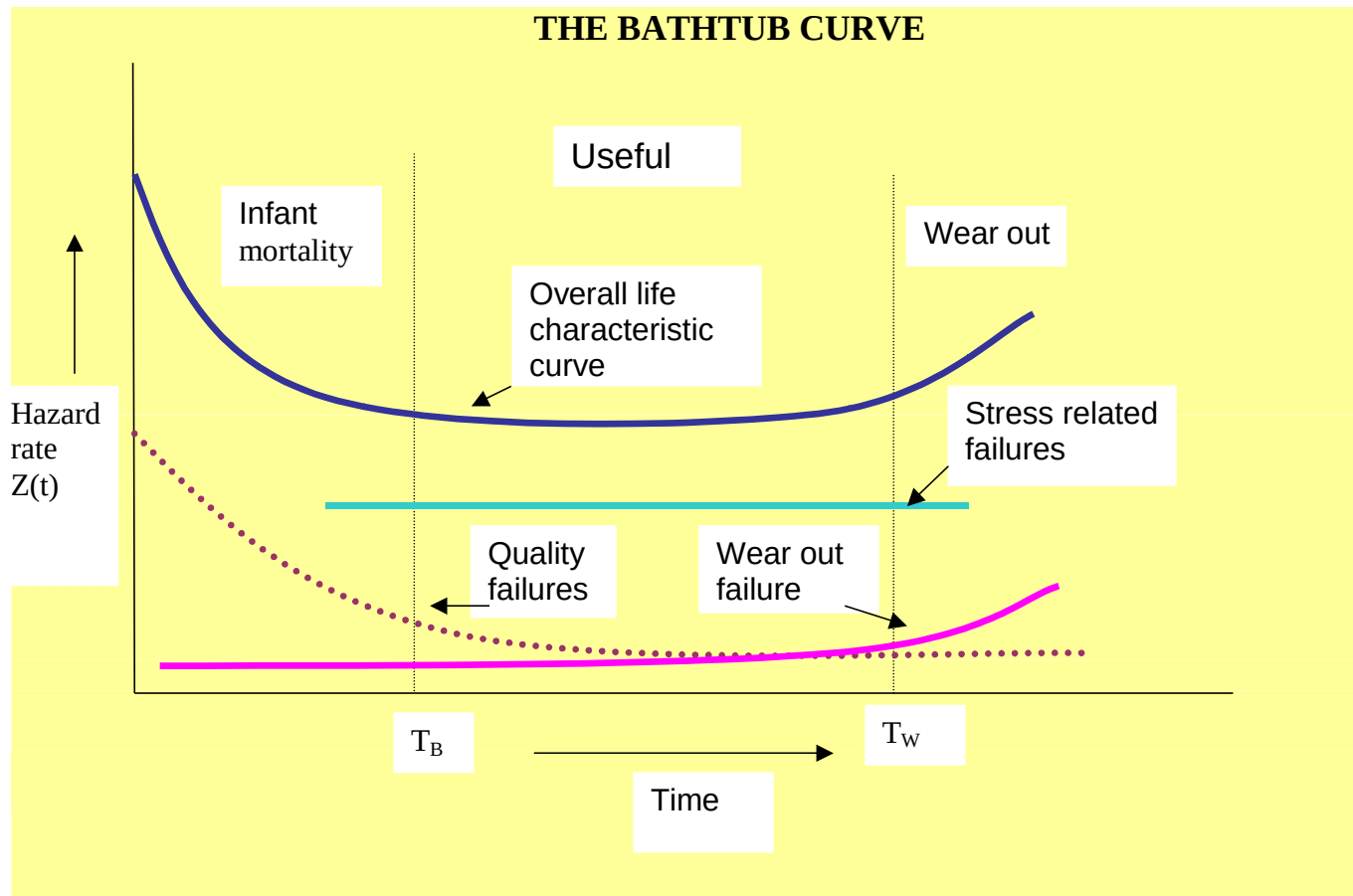
**HEAD
RAED**

**HEAD
RAMD**

Importance of Quality

- ❑ A chain always breaks at its weakest link; a single nut or bolt, a manufacturing step forgotten, a material of inferior strength - can render the product useless
- ❑ Quality management ensures adequacy of methods and contributes to success
- ❑ Importance of quality management increases as the complexity, cost and risk of projects increase
- ❑ The effects of a problem can be devastating in terms of cost, time and public opinion
- ❑ Bath tub curve

The bath tub curve



Quality and Reliability – historic perspective

- Concepts: R and QA discipline has come a long way over the years from Fitness for use to Customer satisfaction covering simple day-today use items to complex Hi-Rel satellites.
 - ▣ Quality : Conformance to specifications on!
 - ▣ Reliability : Probability that system operates properly for a given time under given environment – time dependent
- Need for reliability : Ensures services – economics – safety, Competitive Edge – Security advantage
- Evolution of military standards towards Quality and Reliability Assurance of Parts, materials, processes , systems
- Despite the trend towards faster, cheaper and better devices/, systems demand for higher and higher reliability is increasing

Development of Reliability Engineering

- Reliability engineering as a separate engineering discipline originated in the United States during the 1950s
- The Department of Defense (DOD) issued the AGREE report on testing as a “MIL-STD-781” - Reliability Qualification and production approval tests
- DOD issued MIL-STD-785. “Reliability program for systems and equipment”
- RAMS (Reliability and Maintainability Symposium) - conducted every year in Europe and USA from 1970 onwards.

Space Systems as 'Hi-Rel'

- Space systems classified under Hi-Rel applications
 - ▣ Un-interrupted service requirements (<5 min down time in a year)
 - ▣ Long life missions(12-15 years)
 - ▣ Unattended operations under extreme environmental conditions
 - ▣ Large replacement time (18-24 months)
 - ▣ Substantial replacement cost
 - ▣ National prestige/reputation
- Major components of space systems
 - ▣ Launch vehicle (operational reliability)
 - ▣ Spacecraft (life assurance)
 - ▣ Ground segment (availability)

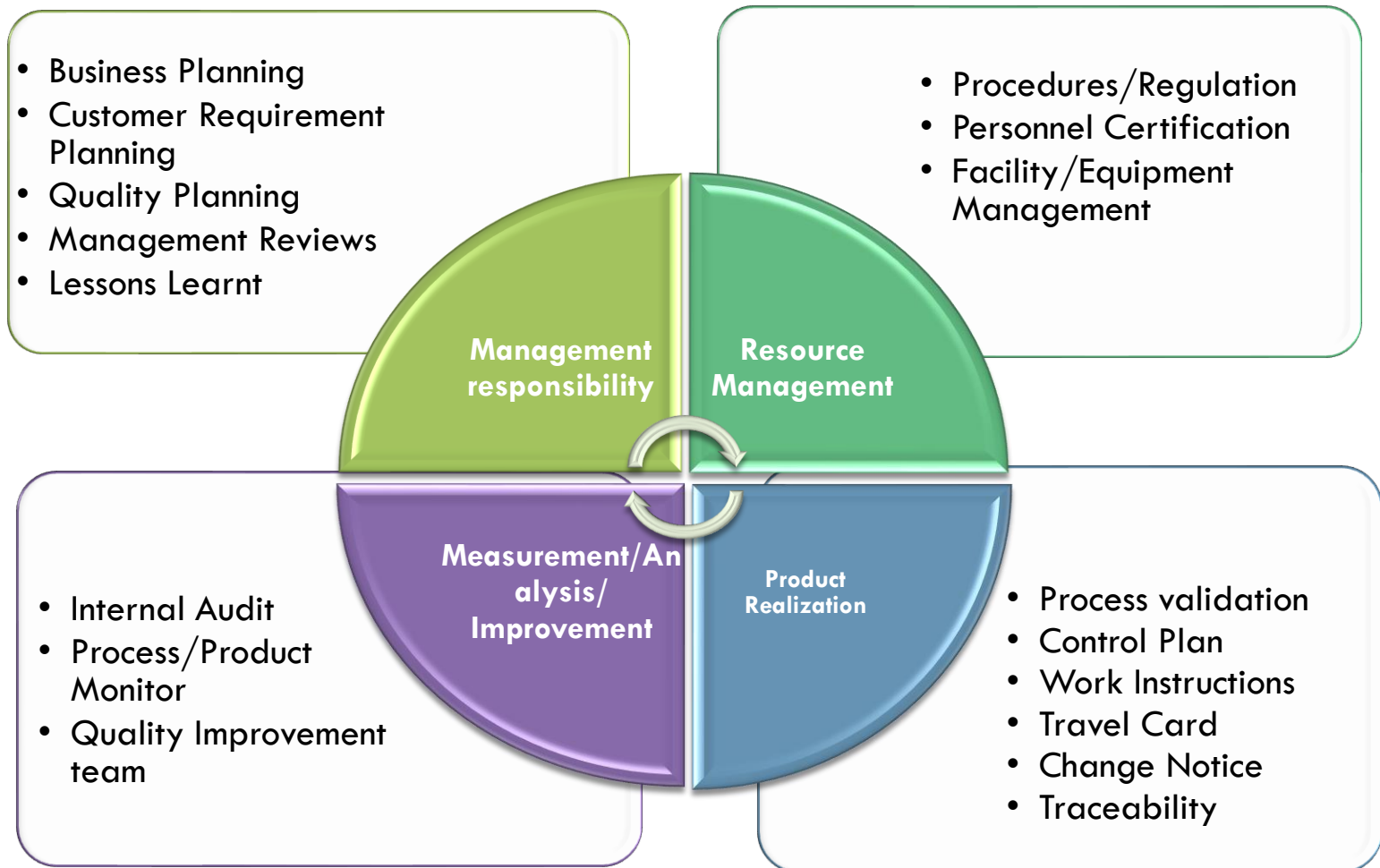
Launch vehicle vs. Spacecraft

Sl.No.	Characteristic	Launch Vehicle	Spacecraft
1	Life	Single shot	Long life (6-15 years)
2	Environment	Temperature, vibration (live for all the systems) ,vacuum (short duration)	Hard vacuum, temperature, vibration (only for few systems live) and Particulate Radiation
3	Testability	Only at Unit level. Integrated test at launch only. Majority of systems cannot be tested prior to launch	System level tests possible to great extent. Difficulties in simulating external interactions. Few systems not testable before launch
4	Manouverability	Totally unattended operation. Only “destruct” feature available	Unattended operation. But limited ground intervention possible
5	Redundancy Management	Active parallel	All types (Standby, Active, Parallel, k out of n)

Unwritten doctrines of space

- Murphy's law – “If anything can go wrong, it will do so when not expected.”
- “ One test is better than thousand expert opinions”
- “ If you cut corners, space will not forgive you”
- “Last minute, untested improvements are blessed with 100 percent failures”

R&Q Assurance approach



Drivers Of Evolution

Service

- End-Use Application
- Life Expectancy
- Down Time
- Risk Assessed Management

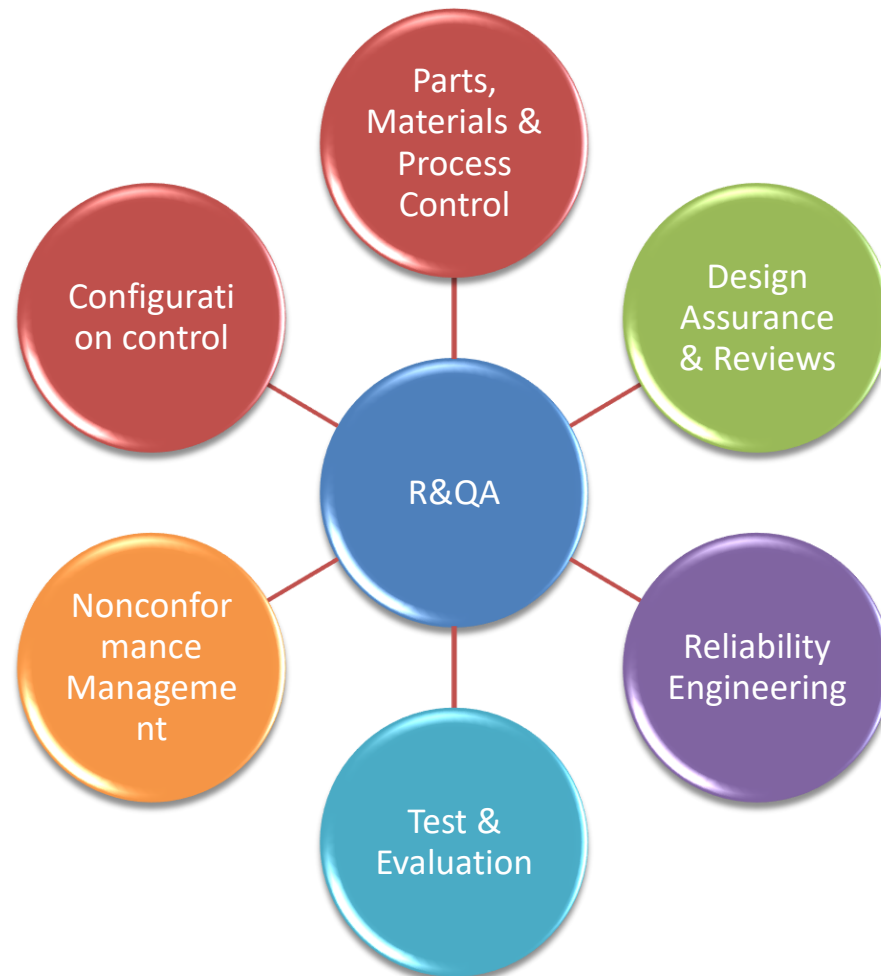
Technology

- Miniaturization
- Advanced Materials
- Software Intensive Designs
- Operational Autonomy
- Up-front user consensus for new developments
- Wider usage of die-shrink components

Changing Global Scenario

Parts Obsolescence
Changing Industry Approaches
Prioritisation of Economic Factors
Paradigm Shift In Standards And Guidelines

R & QA Elements



Reviews

- Following are important mile stones of spacecraft realization
 - ▣ Baseline Design review (BDR)
 - ▣ Preliminary Design Review (PDR)
 - ▣ Critical Design review (CDR)
 - ▣ Test Results Review (TRR)
 - ▣ Pre-Shipment Review (PSR)
 - ▣ Mission Readiness Review (MRR)
 - ▣ Mission Operations Review (MRR)

Reliability Engineering

- Reliability Engineering - Design Principles/Techniques
 - ▣ Design simplicity/robustness
 - ▣ Part selection, specification and control
 - ▣ Parts de-rating
 - ▣ ESD damage prevention
 - ▣ Redundancy
 - ▣ Environmental design
 - ▣ Human factors design
- Reliability Analysis Activities
 - ▣ Worst Case Circuit Analysis
 - ▣ Stress De-rating
 - ▣ Failure Mode Effects Analyses
 - ▣ Reliability Prediction
 - ▣ Fault tree Analysis

Test and Evaluation

- Testing is an essential part of any engineering development program. If the developmental risks are high, the test program becomes a major component of the overall development effort, in terms of time and other resources
- Reliability integrated test program includes
 - ▣ Statistical tests - to optimize the design and processes of the product
 - ▣ Functional testing - to confirm that the design meets the basic performance requirements
 - ▣ Environmental testing - to ensure that the design is capable of operating under the expected range of environments
 - ▣ Environmental Stress Screening(ESS) - to remove workmanship and process-induced defects
 - ▣ Reliability testing - to demonstrate the reliable operation during the expected life
 - ▣ Life Testing - to gain confidence for reliable operation with respect to wear out mechanism
 - ▣ Safety testing - when appropriate

Environmental test sequence (Typical spacecraft systems)

- ❑ Subsystem level
 - ❑ Initial ambient performance
 - ❑ EMI / EMC / ESD
 - ❑ Temperature soak
 - ❑ Vibration - sine / random
 - ❑ Thermal / Thermal vacuum cycling
 - ❑ Specific interface tests - as required
 - ❑ Final ambient performance
 - ❑ Life tests / confidence build-up tests
 - ❑ ESS - approach

Classification of test strategies

- Design Qualification Tests
- Flight Acceptance Tests
- Proto-flight Tests
- Design Qualification Tests
 - These tests are carried out to assess the performance of subsystem / system under simulated environmental conditions more severe than those expected from ground handling, launch and orbital operations
 - Demonstrate margins in design and fabrication methods
 - Environmental levels more severe than actual stresses
 - Assure integrity for repeated acceptance testing (for mechanical loads)
 - Not intended to exceed design and safety limits

Classification of test strategies..cntd..

□ Flight Acceptance Tests

- ▣ These tests are carried out to demonstrate the flight worthiness of systems under simulated environmental conditions - same as those expected during actual operations
 - Assures performance over specified range of mission requirements
 - Reveals latent workmanship and material defects
 - Provides experience with flight systems
 - To establish a base line reference data for actual operations

□ Proto – Flight Tests

- ▣ These tests are carried out on qualification hardware which is required to be flown
 - A combination of qualification and acceptance tests

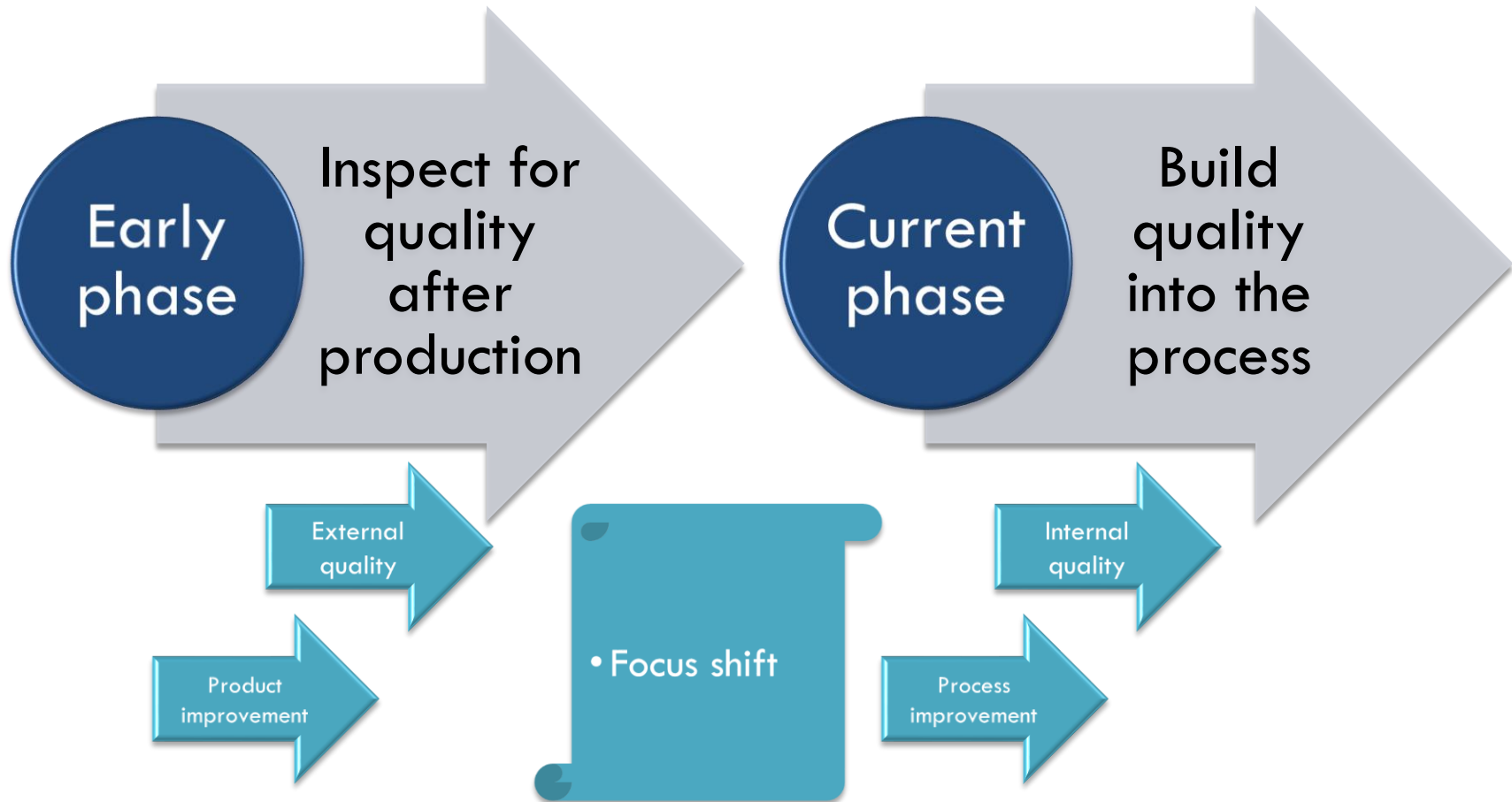
Reliability growth process – ISRO experience

- Phases of Indian Space Programme
 - ▣ Experimental phase
 - ▣ Developmental phase
 - ▣ Operational phase
 - ▣ Productionisation phase
- Sequence followed in R & QA requirements implementation
 - ▣ Generation of guidelines / standards
 - ▣ NASA / ESA standards as baseline reference standards
 - ▣ Tuning of standards based on our own experience (E.g., HMC screening, radiation requirements for LEO)
 - ▣ Test facility build-up (functional and environmental)
 - ▣ Parts / materials control

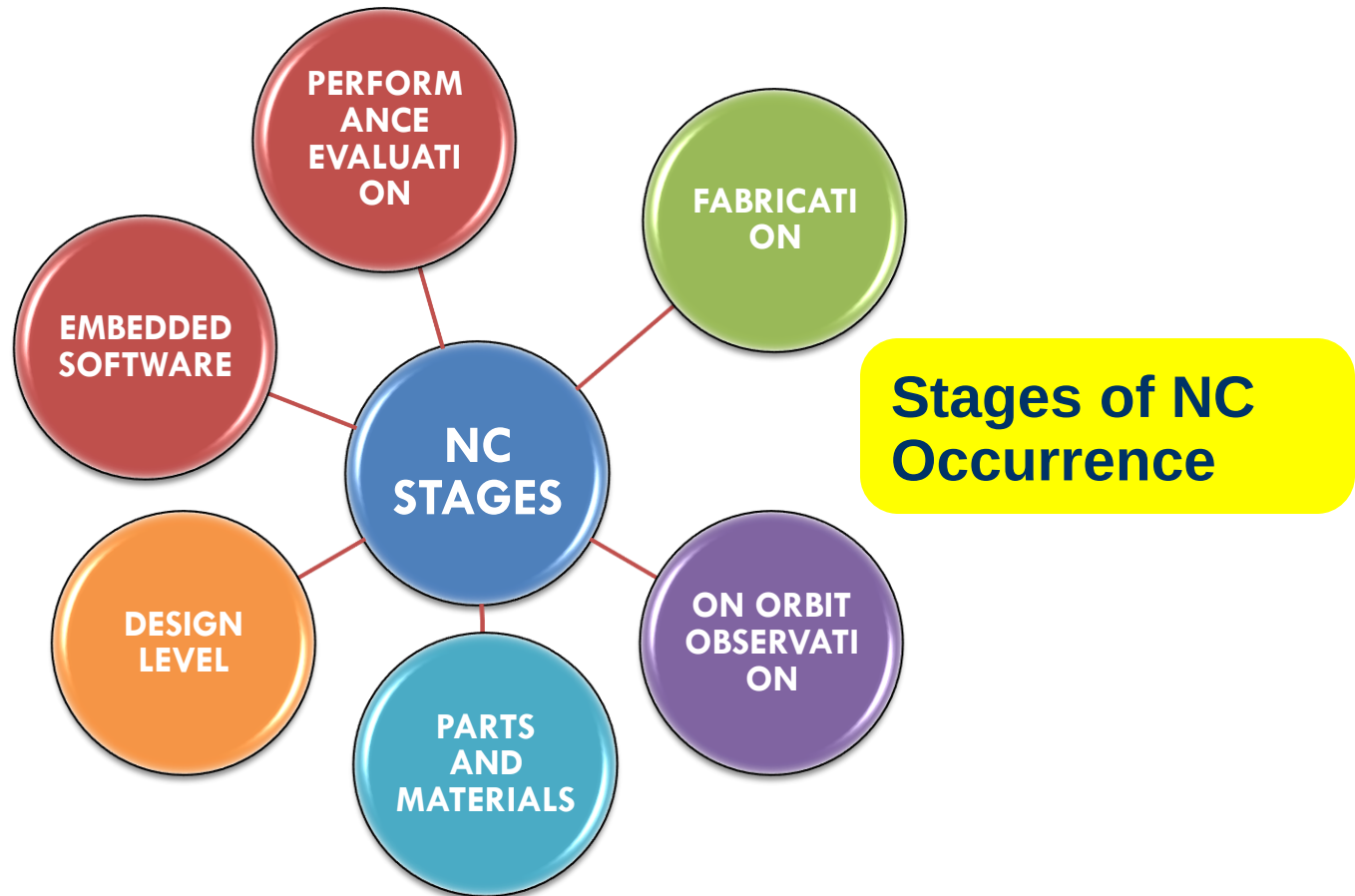
Reliability growth process – ISRO experience

- ❑ Process qualification
- ❑ Wide use of analytical tools
- ❑ Effective failure analysis and systematic non-conformance control
- ❑ Standardization across various work centres
- ❑ Optimization

Process conformance evolution



Non Conformance Management



Non Conformance Control

- ❑ Failure Reporting, Analysis And Corrective Action System (FRACAS)
- ❑ Material Review Board (MRB)
- ❑ Subsystem Review Board (SSRB / CMRB-II)
- ❑ System Review Board (SRB / CMRB-I)
- ❑ Standing Review Committee (SRC)
- ❑ Waiver Methodology

Configuration control

- Establish traceability of;
 - ▣ Realised hardware to the analysed/
designed circuits
 - ▣ Changes wrt to qualified configuration
 - ▣ Changes wrt PPL, DPrI, DML and
approved procedures

Accomplishments

□ Accomplishments : Visible

- ▣ Internationally competitive, state of the art, remote sensing satellites / services
- ▣ Indigenous meteorological / communication satellites, fully meeting the user demands in associated service sectors
- ▣ Leasing / supply of subsystems / systems / services for international customers (INTELSAT, EOSAT, Hughes, MELCO, Matra)
- ▣ Well established industry interface

□ Accomplishments : Invisible

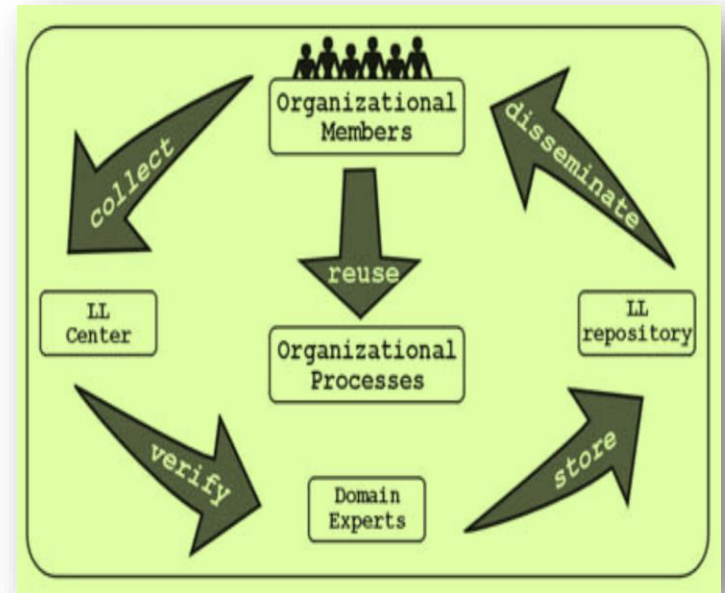
- ▣ Well established and structured R & QA model
- ▣ Openness and transparency in various reviews, a culture nurtured by ISRO (e.g. National Expert Review Committee)
- ▣ Well trained, competent human resource

Challenges

- ❑ Challenges faced during implementation
 - ▣ Very limited industrial support in the initial phases (low volumes, high risk)
 - ▣ Less scope for experimentation / Statistical inferences (limited data availability)
 - ▣ Sanctions / control regimes
 - ▣ Demand Vs schedule
 - ▣ Heritage Vs state of the art
 - ▣ On-orbit anomalies / failures (demanding changes in configuration for projects in advanced stages of implementation)

Lessons learned

- ❑ Screening Out Design Errors
- ❑ Impact of Weak Testing Practices
- ❑ Procedural Errors
- ❑ System Engineering Lapses
- ❑ Mishaps Associated With Software
- ❑ When Processes Break Down
- ❑ A Piece Part Failure
- ❑ Experienced Teams make Mistakes



Core competence of ISRO in R&QA

- ❑ Heritaged designs and comprehensive design reviews through design review committees
- ❑ Well established quality assurance procedures for parts, materials and processes
- ❑ Handling, storage and environmental control of parts and related hardware
- ❑ Test & Evaluation and Reliability Engineering of subsystems and systems
- ❑ Comprehensive qualification , evaluation and acceptance tests for parts, materials, processes
- ❑ Training programs for quality control in the area of fabrication and inspection
- ❑ Traceability control for parts through ICSDBS system and component level failure analysis capability

Core competence of ISRO in R&QA ..cntd..

- ❑ Collaborative technology development projects with academic institutes
- ❑ Special initiative towards ISO 9000 certification and zero defect program across ISRO centres
- ❑ Non conformance management through various review boards
- ❑ Information exchange through quality day workshops and conferences
- ❑ Integrating the lessons learned from ground testing and on-orbit failures for needed changes
- ❑ Hi-Rel assembly specific guidelines, specifications, test procedures , associated documentation and control
- ❑ Internal Quality Audits, Software Quality Assurance
- ❑ Contamination control & Calibration
- ❑ Sophisticated test facilities with well trained manpower

Conclusion

- Quality and Reliability play a major role in all the space programs from their inception. ISRO is no exception and core competence areas are identified
- R & QA practices at ISRO evolved over time, as it's programs entered production phase through operational, experimental and developmental phases
- While adhering to the standard practices / guidelines, R & QA community at ISRO has shown enough flexibility to tailor these, based on our own experience / requirements
- The successful implementation of R & QA requirements can be gauged through the success, which ISRO achieved in it's state of the art remote sensing, communication, meteorology, scientific and inter planetary missions and associated services