

PROJECT MANAGEMENT at ISAC



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NIMANS Convention Centre, Bengaluru

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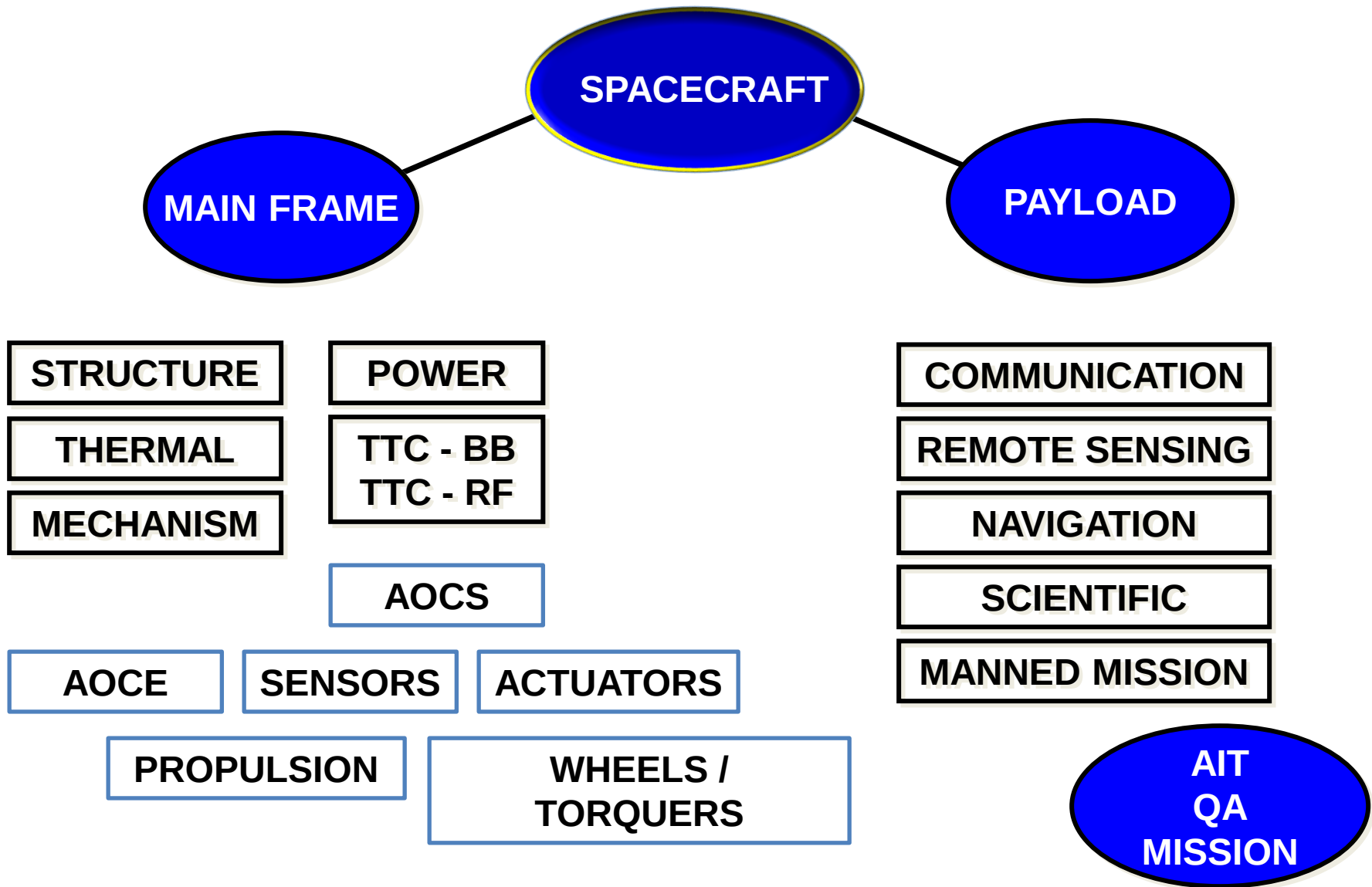
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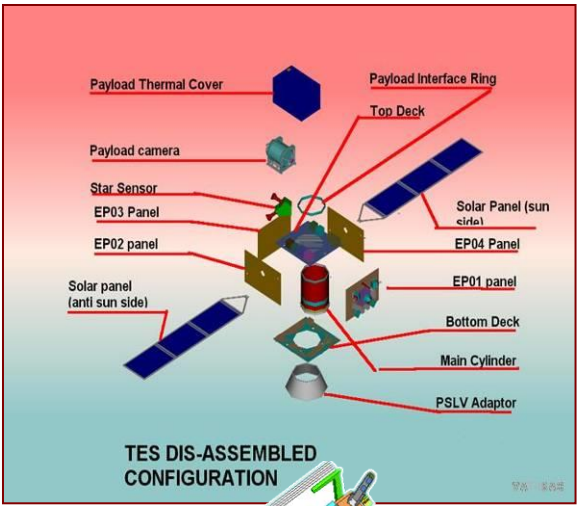
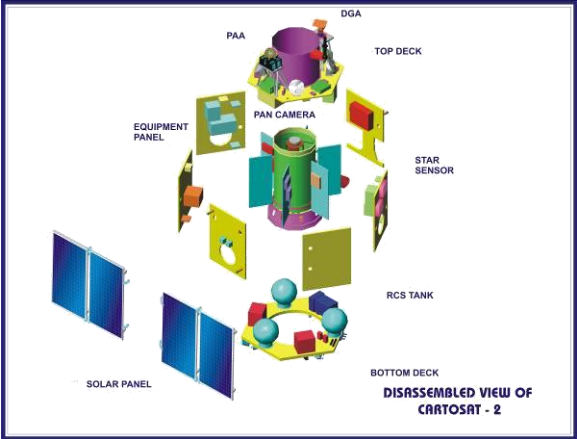
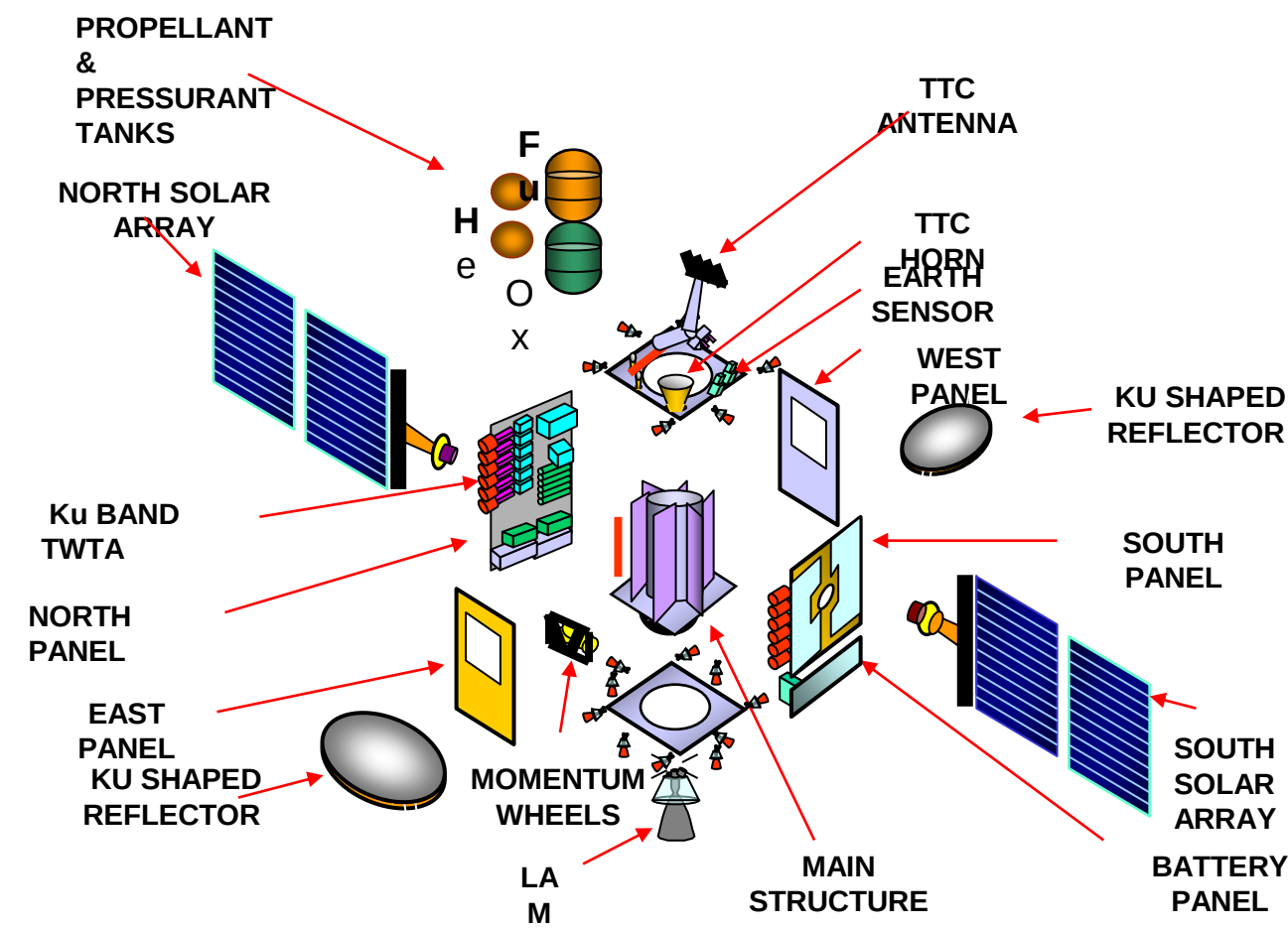
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CONFIGURATION MANAGEMENT

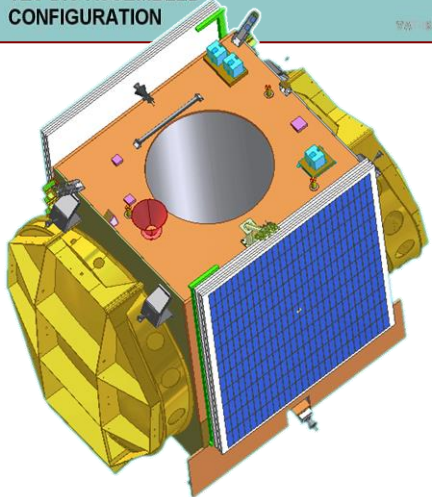
Spacecraft Elements



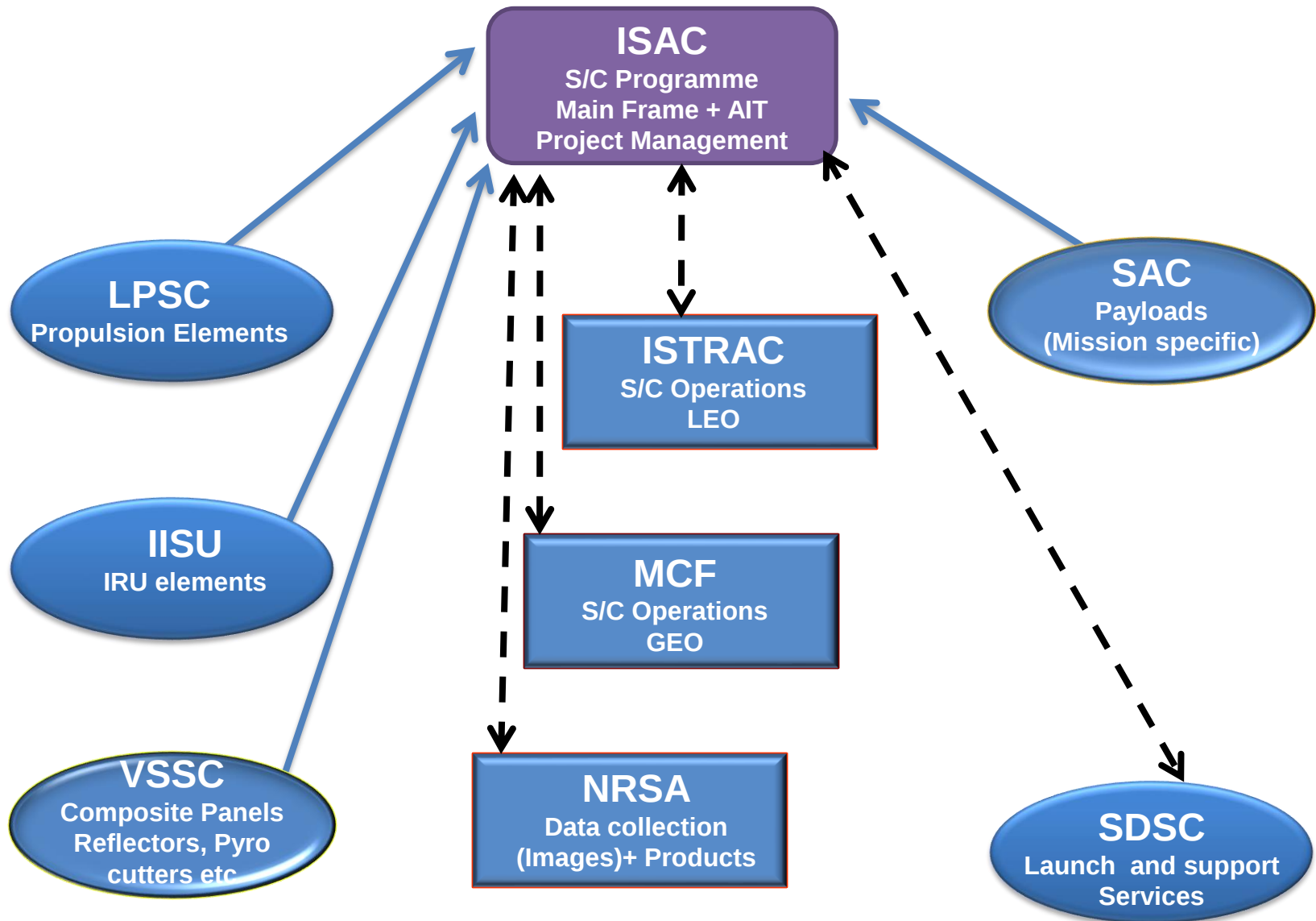
Deployed Configuration



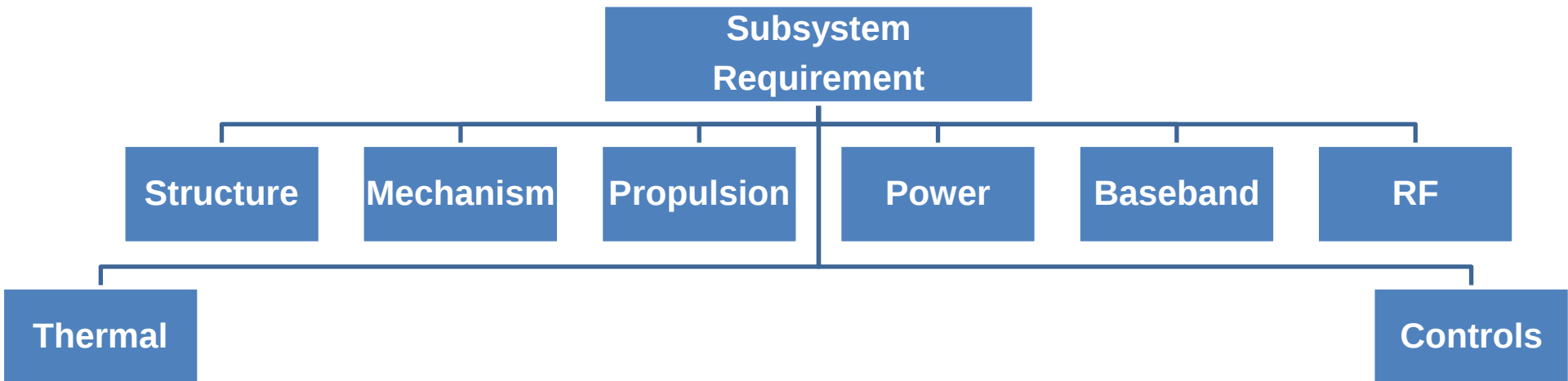
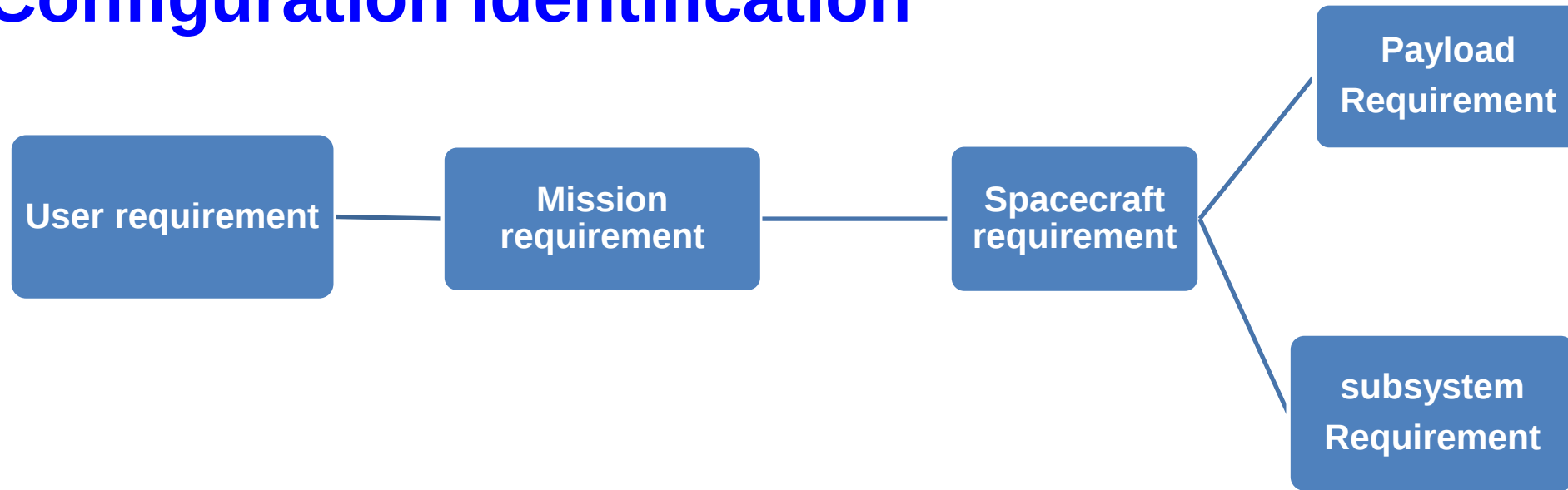
Typical Spacecraft Configuration



Work Centre-Satellite Programme



Configuration identification



Configuration Definition

Important Parameters of Spacecraft

- Mass
- Power
- Payload

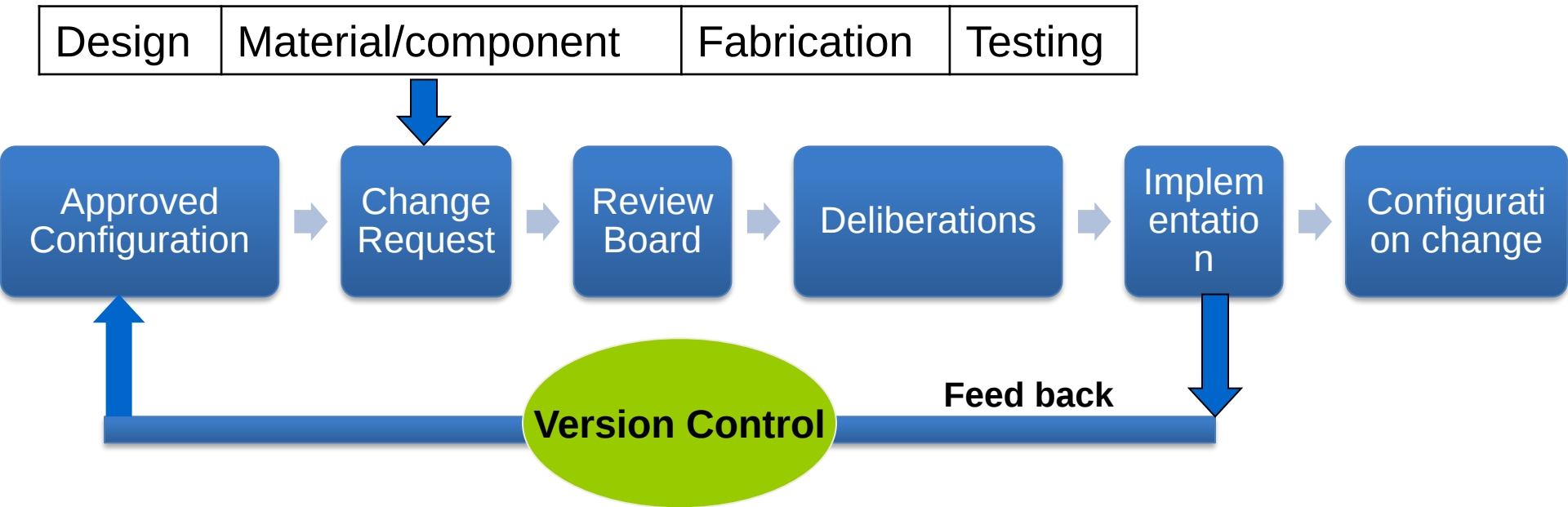
Satellite Design Drivers:

- Reduction in Mass
- Reduction in Cost
- Increase in Reliability
- Increase in System Integration
- Increase in Capabilities For Equivalent Mass
- Reduction in Power Requirements

Subsystem Design Drivers :

- Mission Profile (Maneuvers, Mission Duration, Distances, Angles)
- Payload Requests (Mass, Volume, Pointing, Data Handling, Thermal needs, Power, Cleanliness)
- Launch requirements (Mass, Volume, Mechanical Loads & Frequency)
- Ground Segment Constraints
- Technical Complexity

Configuration Control



Review Boards

PRB: Parts Review Board

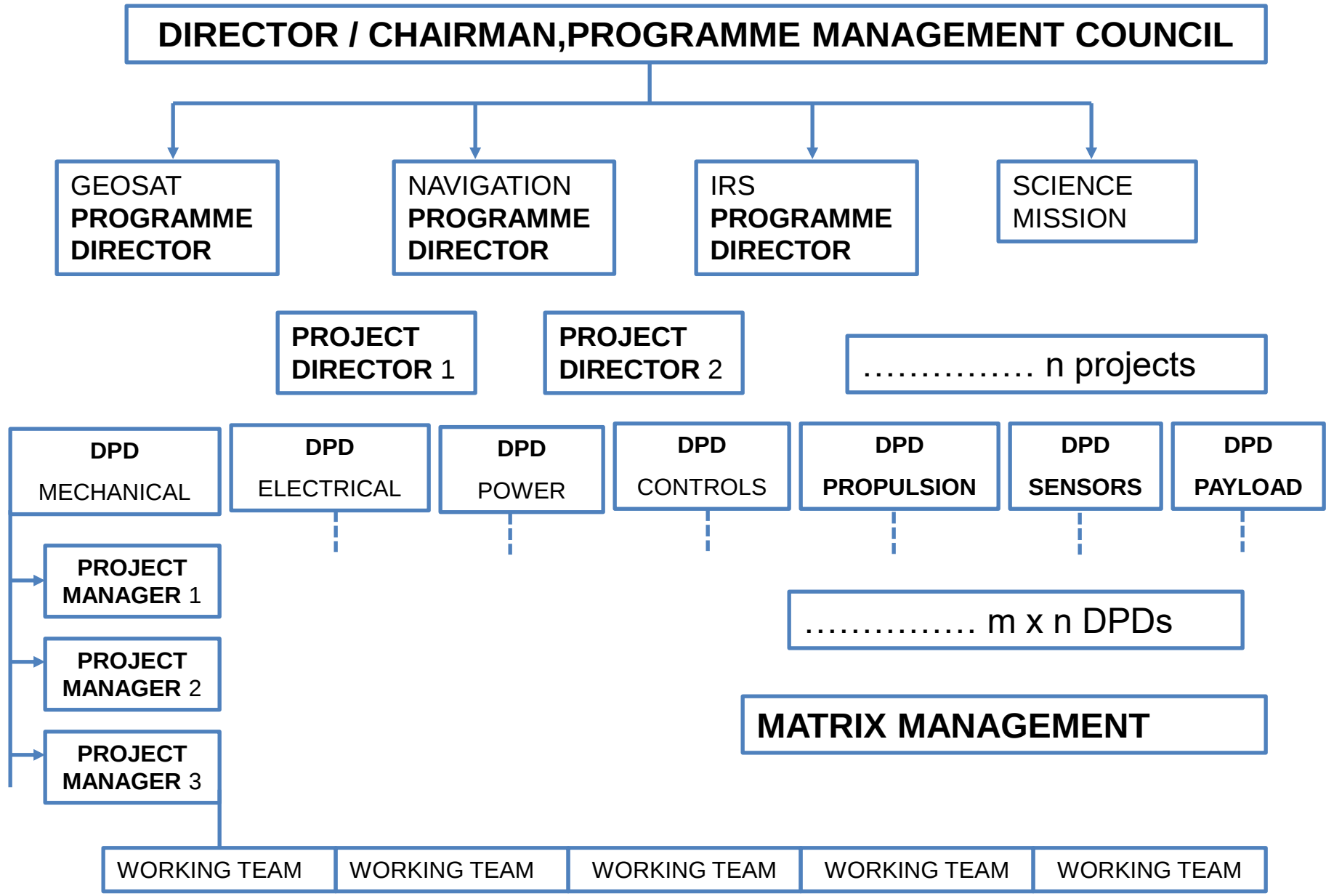
MRB: Materials Review Board

CMRB: Configuration Management Review Board

SRC: Standing Review Committee

ORGANISATION STRUCTURE

Project Organization Structure



Matrix Management- Satellite Perspective

- **Multi Project Environment:** To build various projects for Communication, Remote sensing, Navigation & Space science applications
- **Optimum Utilisation Of Resources**– Effective utilization of all Resources (Manpower expertise, Money & Material, & Machines)
- **Concurrent Engineering** – Geographically Distributed work centres
- **Improved Responsibility & Accountability**
- **Decision Making Process** – Review from component level to spacecraft level
- **Promotes Team Work & Team Building** – Health work environment and competition
- **Balancing Technology Growth And Project Load**

FUNCTIONAL ORGANISATION (TECHNOLOGY MANAGEMENT)

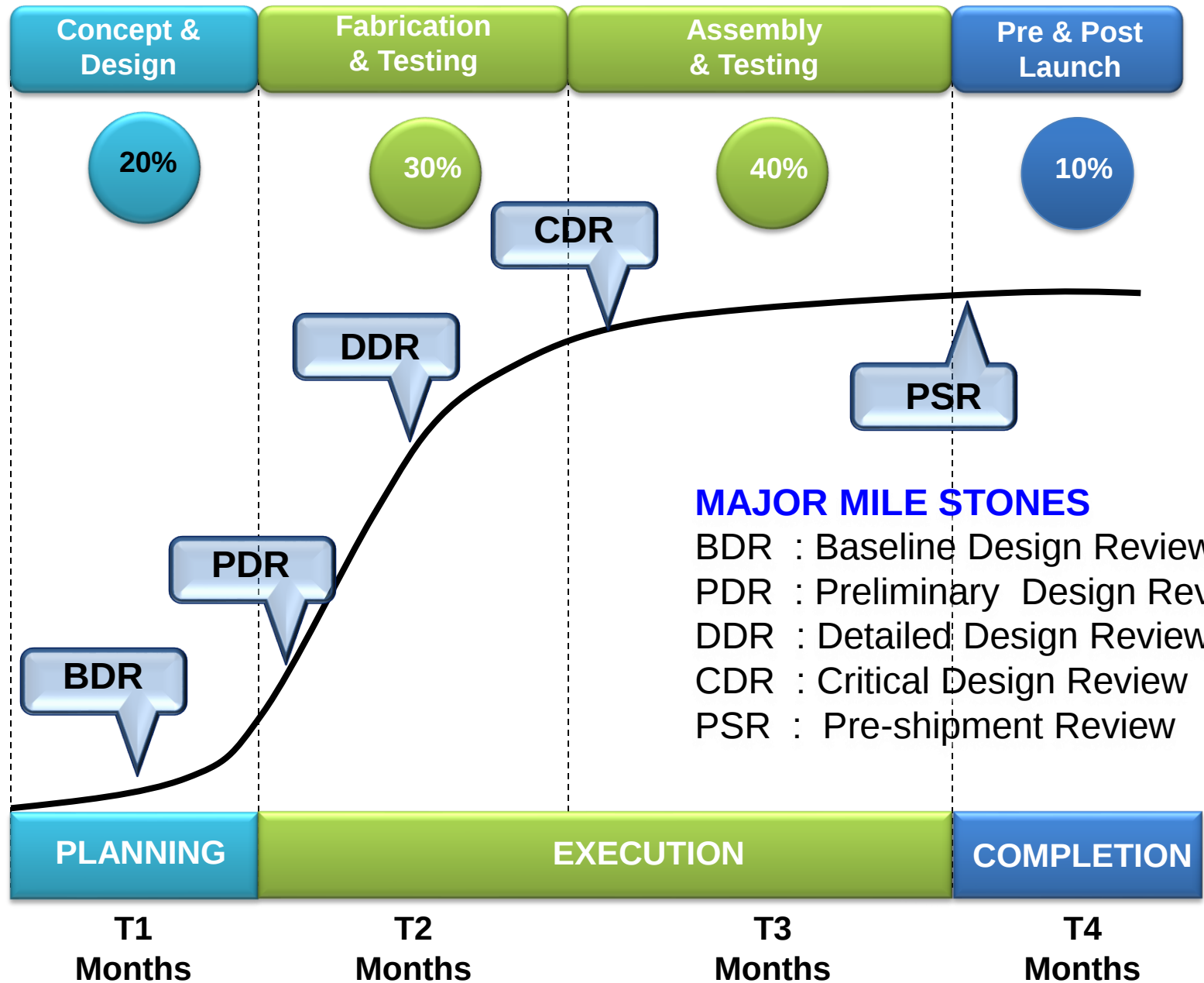
1. Domain expertise
2. Fostering innovation
3. Technology forecasting
4. Space quality and reliability
5. Knowledge management & documentation

PROJECT ORGANISATION (PROGRAMME MANAGEMENT)

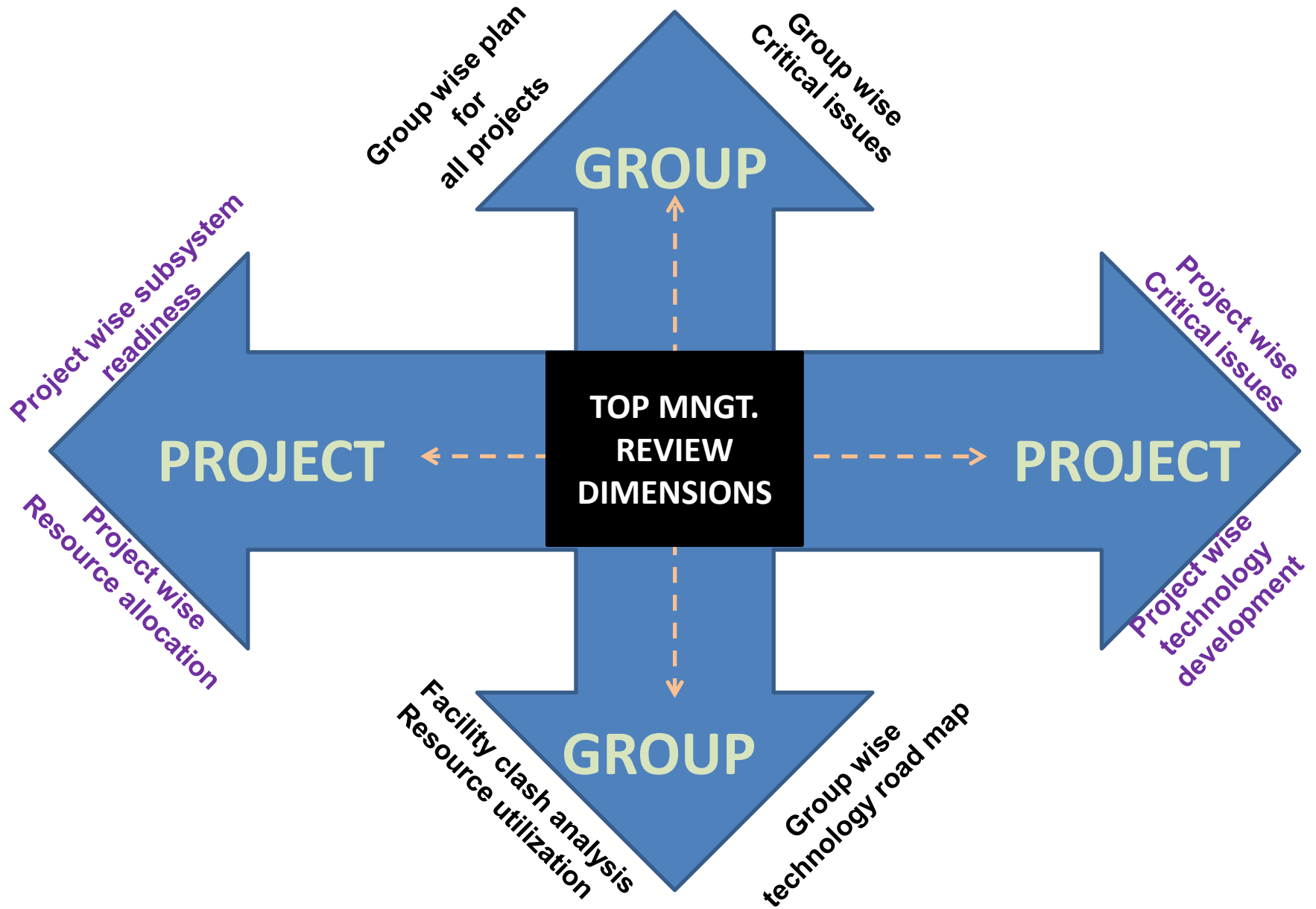
1. Satellite bus standardisation & subsystems productionisation
2. Configuration management
3. Timely project execution
4. Lessons learnt data base
5. Seamless information flow
6. Documentation control

REVIEW MECHANISM

Project Life Cycle- A Typical View



Two Dimensional Review Mechanism



Two Dimensional Review Mechanism

ISRO COUNCIL – PLANING & MONITORING

PROGRAMME MNGT COUNCIL

- Programmatic Targets set forth
- Spacecraft performance & On-orbit anomalies
- Ongoing projects Overview

CENTRE LEVEL COUNCIL

- Integrated Project Plan
- Critical Technology Development
- Infrastructure Development
- Manpower training & development
- Budget Analysis
- Centre work load Assessment



ORGANISING & DIRECTION

1. PROJECT MNGT BOARD

- Subsystem configuration definition
- Subsystem realization philosophy
- Schedule Analysis
- Project Configuration change
- Inter centre co-ordination

AREA LEVEL COUNCIL

- Domain specific Technology Development
- Project Deliverable commitments
- Budget Analysis
- Manpower workload



EXECUTION

PROJECT MEETING

- Subsystem status
- critical issues/Bottlenecks
- Non-conformity
- Configuration control

GROUP LEVEL MEETING

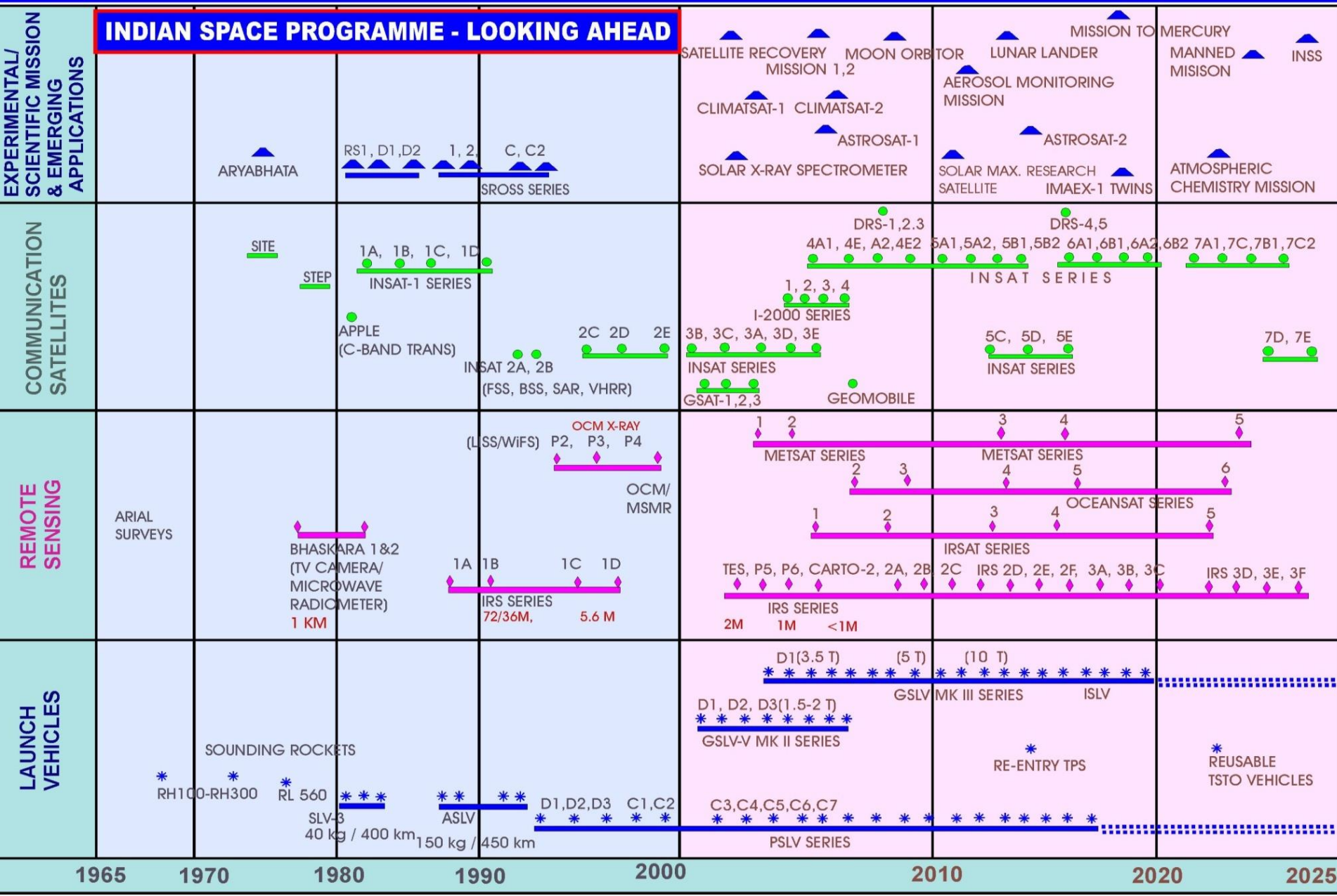
- Project Deliverables due dates
- critical issues/Bottlenecks
- Productionization efforts
- Manpower Deployment

STRATEGIC PLANNING & SCHEDULING

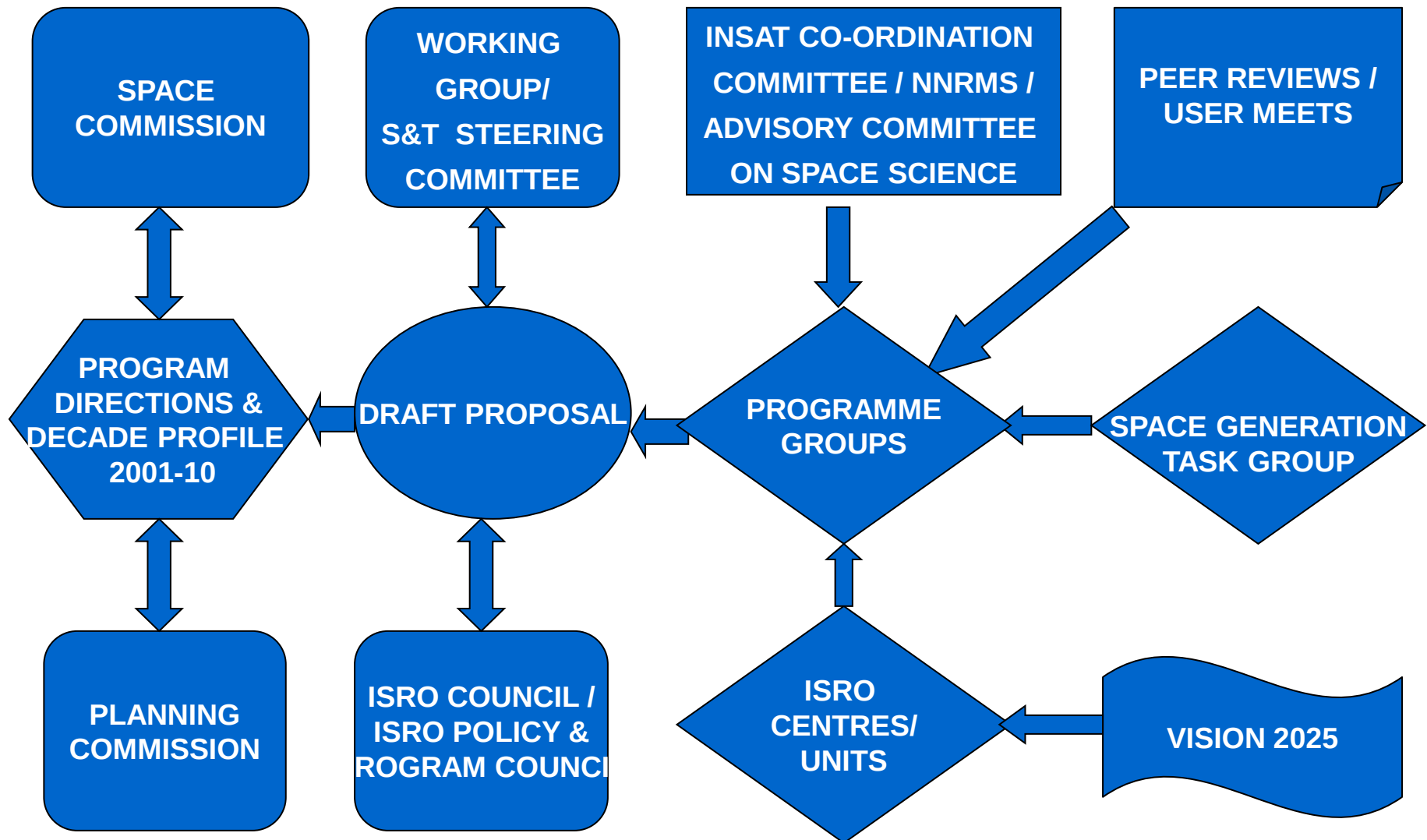
Strategic Management

25 year plan	1. socio-economic development of the nation using space technology 2. Self reliance in satellite technology 3. Establishment of space systems for operational services
Decade Plan	1. Continuity of INSAT system 2. Continuity of IRS system 3. Development and establishment of of Navigation systems 4. Research and development in space sciences and planetary exploration 5. Technology, infrastructure and manpower development
5 Year Plan	1. Programmatic targets- Communication, Earth observation, Navigation and Space sciences 2. Development of advanced technology 3. Infrastructure and Capacity Building
2.5 Year Plan	1. Programmatic targets – Detailed project schedules for the next 2.5 years 2. Development of Project related technologies 3. Extend of Productionization-Outsourcing
Annual Plan	1. Project milestone plan 2. Subsystem Delivery schedule 3. Resource planning 4. Workload Analysis 5. Facility Load Pattern
Monthly Plan	1. Project Work breakdown structure, 2. Gantt chart,Network diagram 3. Project Dashboard

25 Year Plan



Plan Formulation process

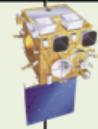
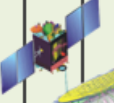
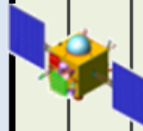


Five Year Plan

12th FIVE YEAR PLAN MISSION PROFILE (2012 -2017)

Total Missions : 58 (Satellites: 33) Launch vehicles: 25)						
MISSIONS	2012-13	2013-14	2014-15	2015-16	2016-17	2017- 18
EARTH OBSERVATION SATELLITES	SARAL 		CARTO-2C 	RESOR-2A  CARTO-2D 	OCEAN-3  CARTO-3  GISAT 	RISAT-1A  SCATSAT-1 
COMMUNICATION & NAVIGATION SATELLITES	IRNSS-1  GSAT-14  Procured Launch Service INSAT-3D GSAT-10 	IRNSS-2 IRNSS-3  GSAT-6  GSAT-7 GSAT-15 	IRNSS-4 IRNSS-5 IRNSS-6  GSAT-16 GSAT-11 	IRNSS-7  GSAT-9  GSAT-17 GSAT-18 	 GSAT-6A  GSAT- 19E  GSAT-11S GSAT-Ka 	GSAT-7A  INSAT-3DR  GSAT- 20  GSAT-21(P) (satellite procured) 
SPACE SCIENCE & PLANETARY EXPLORATION SATELLITES		ASTROSAT  MARS 	CHANDYAAN-2 		ADITYA 	MARS-2 
INDIAN LAUNCH VEHICLES	C20 C21 C22 D5 X1 Antrix Exp 	C23 C24 C25 C26 D6 	C27 C28 C29 C30 F08 	C31 C32 C33 F09 Antrix 	C34C35C36 F10F11 D1 	C37 F12 F13 D2 

Execution Plan

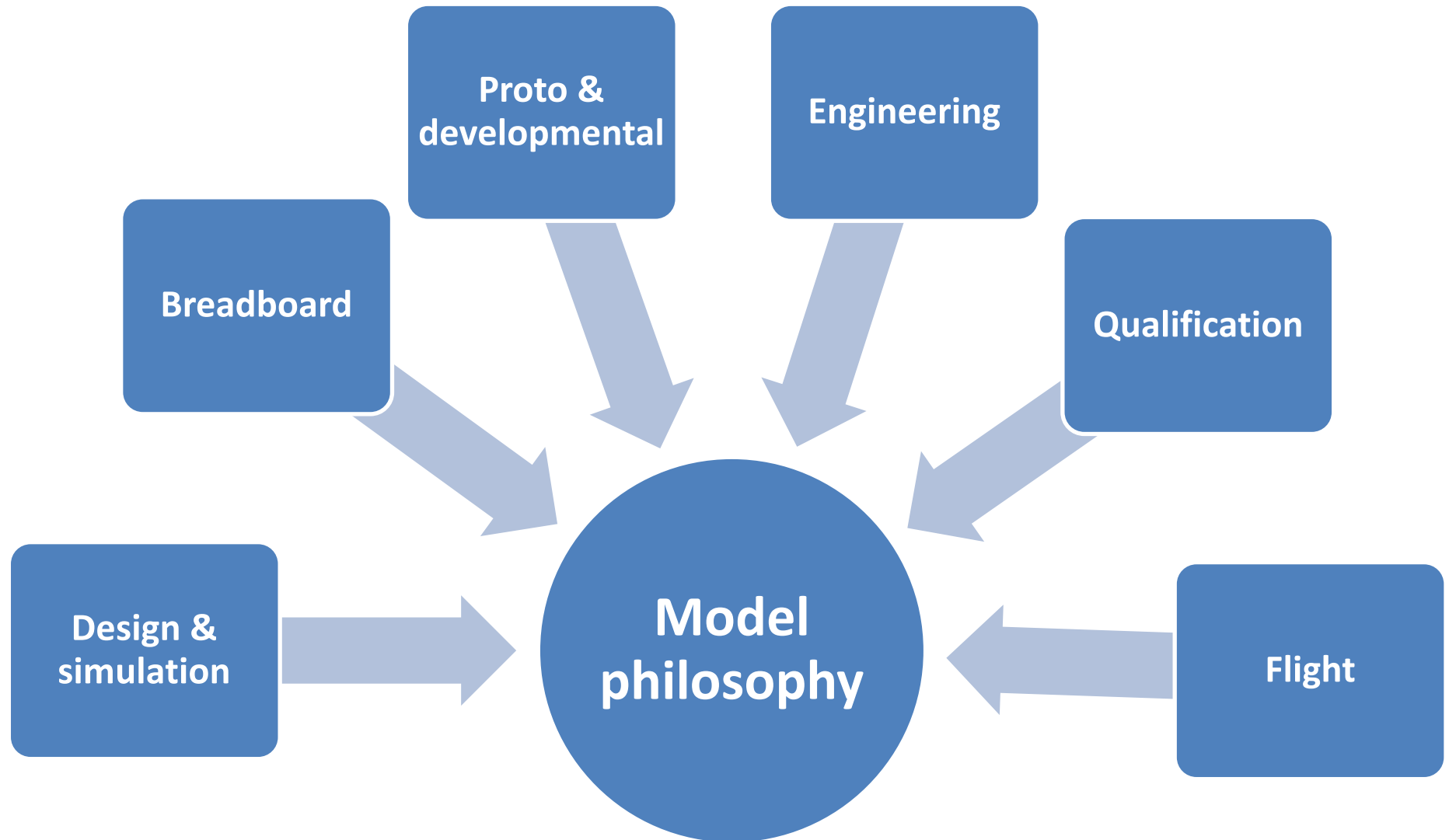
	2014 (4 spacecraft)						2015 (11 spacecraft)												2016 (13 spacecraft)											
	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
GEOSAT	 GSAT-16 PROCURED			 GSAT-6 GSLV			 GSAT-15 PROCURED		 GSAT-7A GSLV		 GSAT-18 PROCURED		 GSAT-17 PROCURED		 INSAT-3DR GSLV				 GSAT-11 PROCURED		 GSAT-9 GSLV		 INSAT-3DS GSLV		 GSAT-6A GSLV	 GSAT-19 GSLV MK-III D1		 GSAT-Ka PROCURED		
IRS & SSS												 ASTROSAT PSLV		 CARTOSAT-2C PSLV							 RESOURCESAT-2A PSLV			 CARTO-2D PSLV		 EMISAT PSLV				
													 SCATSAT PSLV												 MICROSAT PSLV		 DOCKING B PSLV			
NAVIGATION	 IRNSS-1C PSLV	 IRNSS-1D PSLV					 IRNSS-1E PSLV			 IRNSS-1F PSLV		 IRNSS-1G PSLV							 IRNSS-1H PSLV		 IRNSS-1I PSLV									

TECHNOLOGY MANAGEMENT

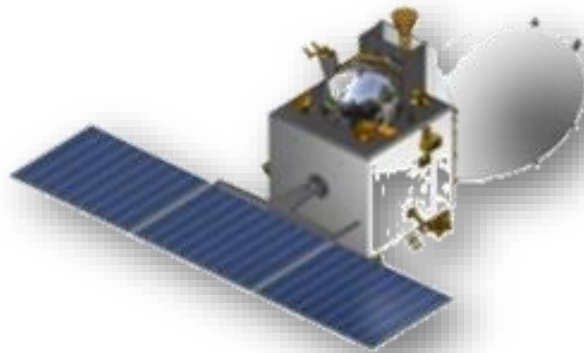
Technology Management-Challenges

- **Satellites have to work in hostile space environment for several years**
- **All parts/subsystems used in the satellite should have very high reliability along with space quality standards.**
- **Selection of parts/components, Extensive qualification of process and fabrication, elaborate testing of various subsystems under different environment conditions are pre-requisites to ensure long life and reliability**
- **Time consuming and expensive : requires special expertise and facilities. All the facilities have been established**
- **Sophisticated design tools have been developed in the centre for design , analysis and testing of satellites**

Technology Development – Model philosophy



MARS ORBITER MISSION SUCCESS STORY



MARS ORBITER MISSION SALIENT FEATURES

Mars Orbiter Mission-Overview

ISRO's first interplanetary mission to Mars planet with an orbiter craft designed to orbit Mars in an elliptical orbit. The scientific payload instruments are intended to study surface features morphology, topology and mineralogy of Mars, Constituents of Martian atmosphere. The Earth-Mars trajectory comprises of three phases namely, Earth-centered phase, Heliocentric phase and Martian phase.

SALIENT FEATURES

Orbital Location : 370 X 80,000 Kms elliptical orbit

Voyage from Earth's orbit : 300 Days

Mass : 1350 Kg

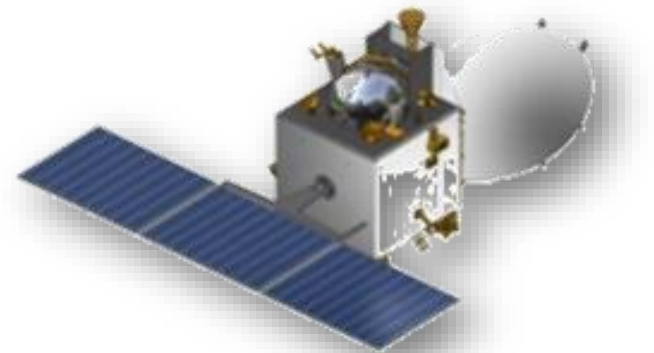
Power : 750 W

Mission Life : ~ 6 Months

Launcher : PSLV C 25

Payload : Lyman Alpha Photometer, Methane Sensor for MARS, Martian Exospheric Composition Explorer, MARS Color Camera and TIR Imaging Spectrometer

Launch Date : 5th November , 2013



Mars Orbiter Mission- Mission Objective

Technological objectives:

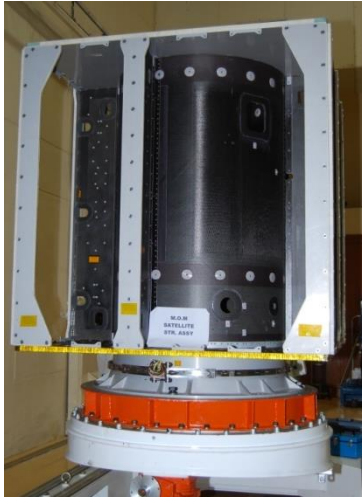
- Design and realisation of a Mars orbiter spacecraft with a capability to survive and perform Earth bound manoeuvres, cruise phase, Mars orbit insertion and capture, and on-orbit phase around Mars.
- Deep space communication, navigation, mission planning and management.
- Incorporate autonomous features to handle contingency situations

Scientific objectives:

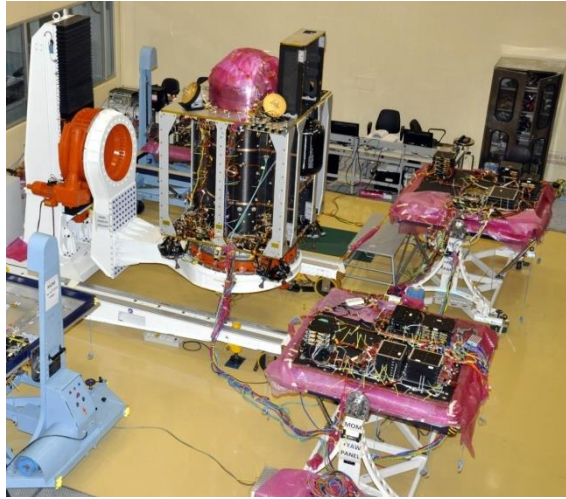
- Exploration of Mars surface features, morphology, mineralogy and Martian atmosphere by indigenous scientific instruments.

MARS ORBITER MISSION MAJOR MILESTONE

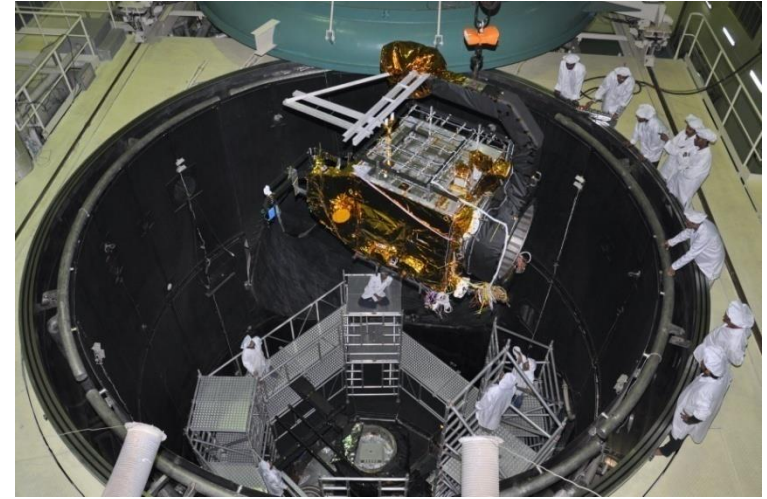
Mars Orbiter Mission-Making



**Structure
Delivery at
Clean Room**



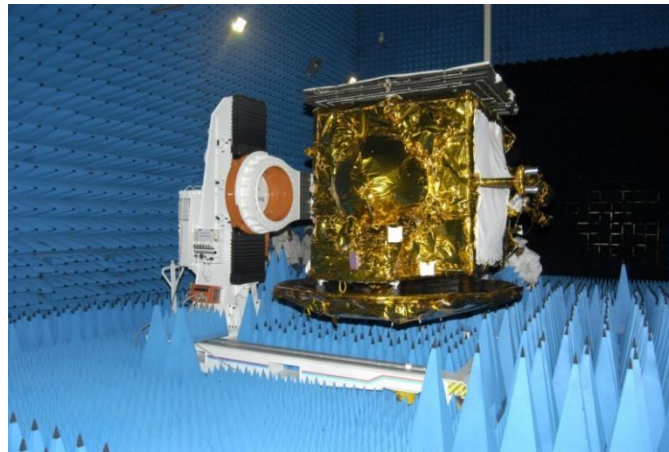
**Subsystem Integration
activities in Clean Room**



Loading to Thermovac Chamber



Antenna Deployment Test



EMI/EMC Test

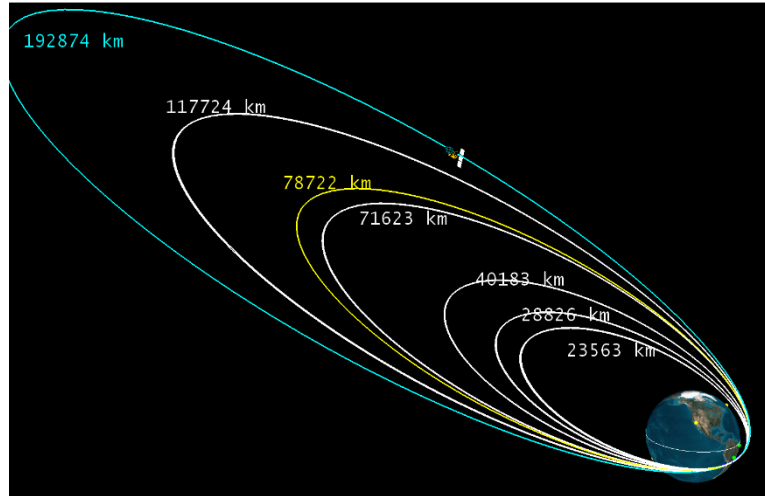


Vibration Test

Mars Orbiter Mission- Sequence of Event



**Launched onboard
PSLV-C25 on
November 5, 2013**



**Six orbit raising manoeuvres to
raise the apogee**



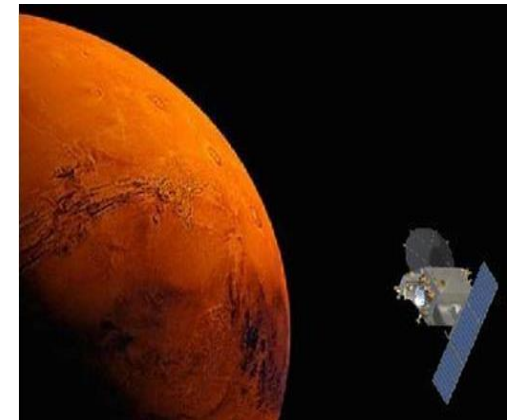
**Trans Mars Injection
on December 01, 2013**



**Main Liquid Engine
Successfully restarted on
September 22, 2014**



**Inserted into Mars Orbit
Honourable Prime Minister of
India, Mr Narendra Modi
Witnessed the event**



MOM orbiting Mars

Mars Orbiter Mission- Data Products

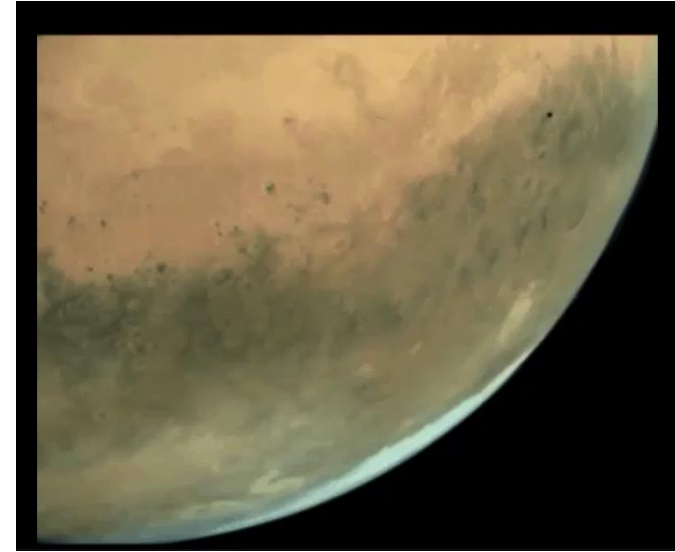
Full disc image of Mars, taken by the Mars Color Camera, from an altitude of 66,543 km.



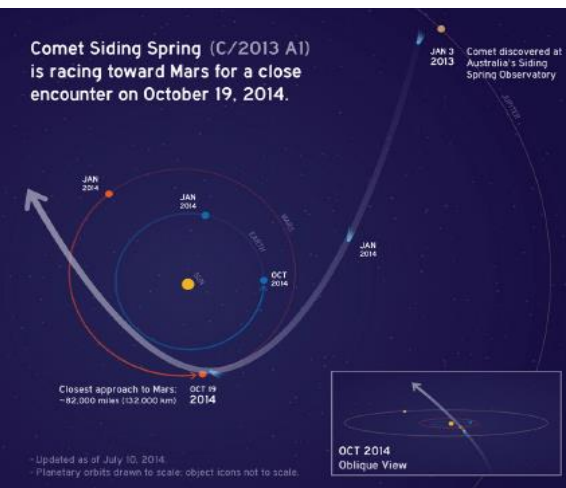
Google doodle- on 1 month completion of Mom



**Image of Phobos, the larger of the two
Martian moons taken by the MOM**



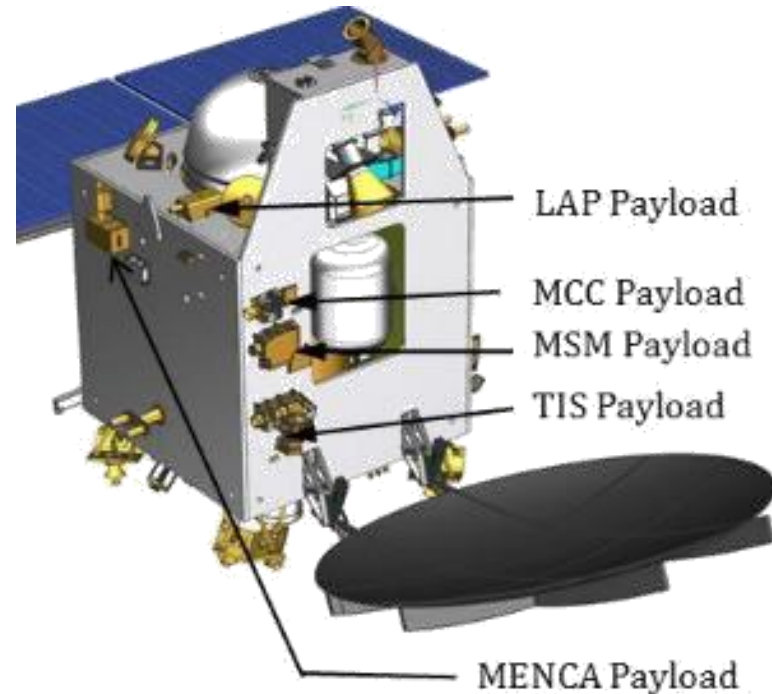
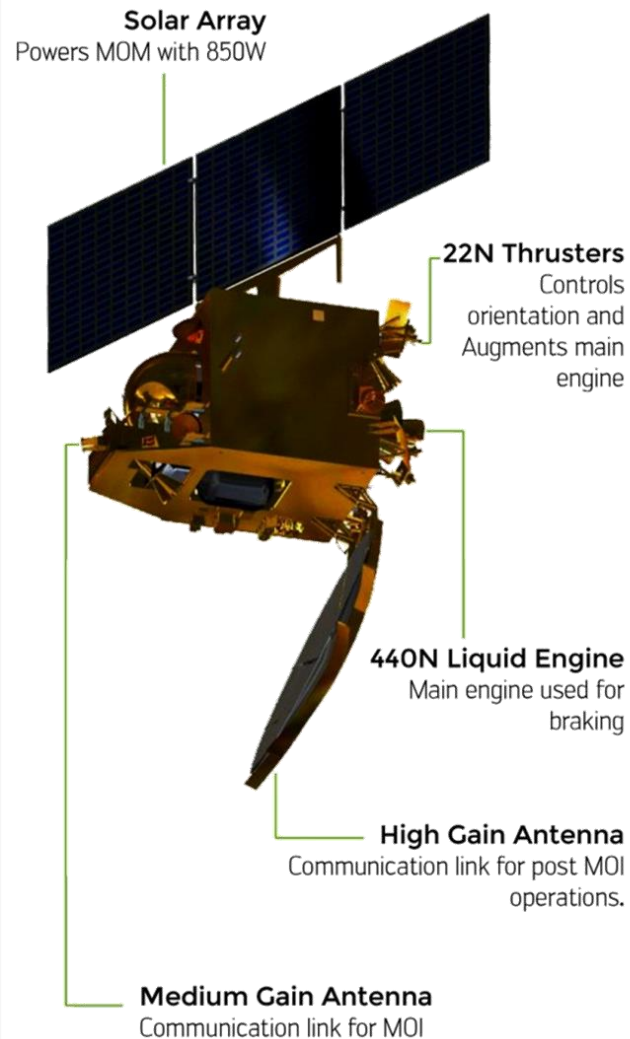
Mom encounter with the comet Siding Spring on October 19, 2014



MARS ORBITER MISSION MAJOR CHALLENGES

Mars Orbiter Mission- Critical Systems

- Propulsion system
- Power system
- Communication system
- Spacecraft Autonomy
- Thermal system.



Mars Orbiter Mission- Critical Systems

Propulsion System	
Challenges:	Solutions:
To restart the Liquid Engine after 10 months for Martian Orbit Insertion (MOI) manoeuvre.	Two Liquid Engine hardware were ground tested in ISRO facility, IPRC at Mahendragiri after subjecting them for near flight conditions.
Power System	
Challenges:	Solutions:
No power generation during MOI due to eclipse. Very low temperature of solar panels during eclipse periods (-185 Deg C).	• The ground battery identical to the one used in MOM was characterized . • Prior to launch, the low temperature qualification test was conducted at coupon level to qualify it for -210 deg C.
Communication System	
Challenges:	Solutions:
Communication management in Earth bound phase, cruise phase, MOI and Martian orbit phase.	Solutions: Analysis for MOI using Thermal Mathematical Model carried out

Mars Orbiter Mission- Critical Systems

Spacecraft Autonomy	
Challenges:	Solutions:
▪ Limited visibility of the spacecraft ▪ Limited uplink and downlink volume	On-board autonomy is achieved through • Autonomous Fault Detection, Isolation and Reconfiguration (FDIR) logics • Master Recovery Sequencer(MRS) • Putting it in Safeguard Mode • The command modules meant for execution of MOI autonomously were tested extensively for its correctness in an exclusive ground hardware simulation set up.
Thermal System	
Challenges:	Solutions:
The spacecraft needs to cope with a wide range of thermal environment	• Analysis for MOI using Thermal Mathematical Model carried out.

Mars Orbiter Mission- Mission Planning

- Trajectory generation for all phases of Mission
- Maneuver strategy design and analysis package
- Attitude steering profile generation for all phases & Attitude analysis
- Orbital events generation
- Orbit determination system considering range, doppler and DDOR measurements for various phases of the Mission
- Onboard orbit models for Heliocentric and Martian Phases
- Onboard attitude steering for Heliocentric and Martian Phases
 - Model based as well as coefficients based
 - Verification of OIL's results completed
- Proximity analysis with asteroids in Cruise phase and Phobos & Deimos in Martian Orbit phase & with Comet A13

Mars Orbiter Mission- Flight Dynamics

Optimum Launch Opportunities

Year	P.O. Incl. (deg)	Depart. Date	Transf. Time (days)	Mars Arrival Date	V-inf Decl. (deg)	Dep. Traj. AOP (deg)	Trans-Mars DV (km/s)	MOI DV (km/s)	Total DV (km/s)
2013	18	Nov 27	301	24 Sep 2014	17.81	293	1.521	1.071	2.592
	19.2	Nov 29	300	25 Sep 2014	19.16	297	1.507	1.072	2.579
	25	Dec 4	294	24 Sep 2014	24.04	285	1.485	1.072	2.557
2016	18	Jan 10	275	11 Oct 2016	9.50	246	1.593	1.377	2.970
2018	18	May 17	239	11 Jan 2019	-17.97	121	1.405	1.160	2.565
	40	May 12	204	2 Dec 2018	-36.63	139	1.410	0.963	2.373

Mars Orbiter Mission-Tracking Network

ISTRAC Stations

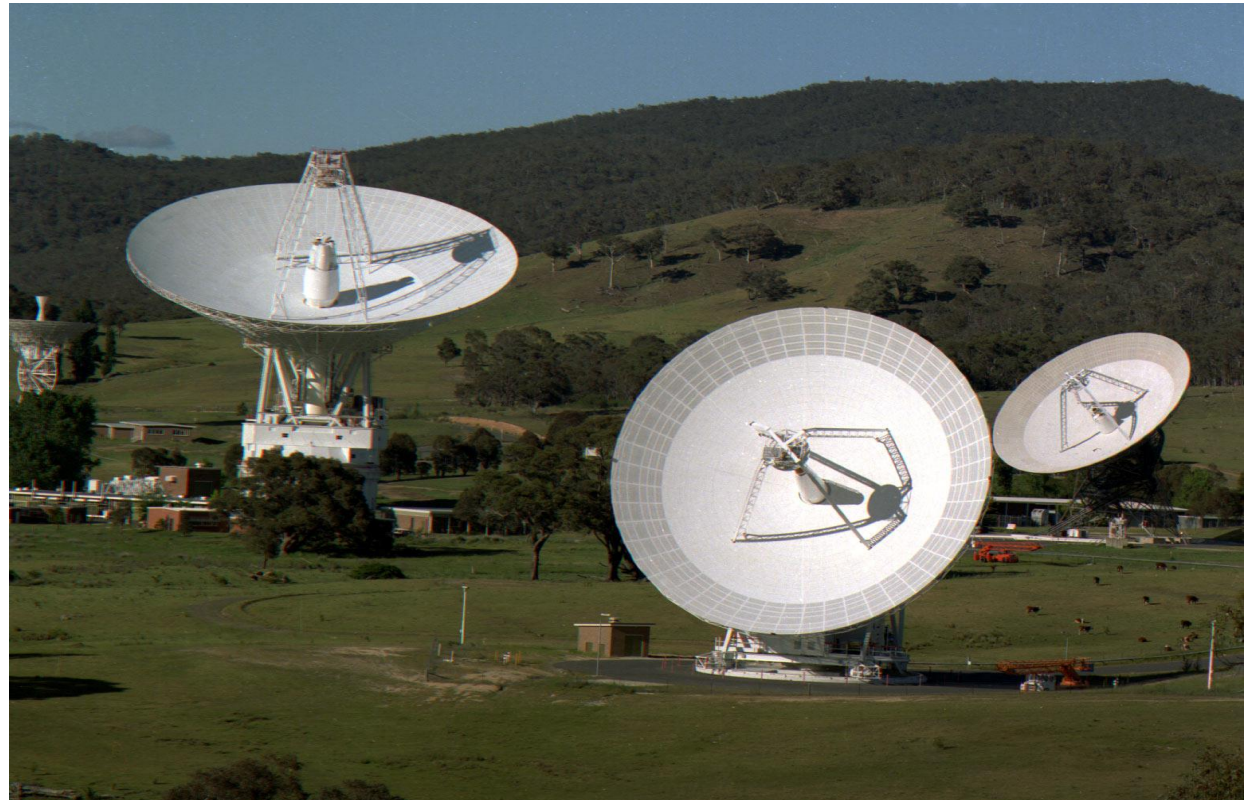
Bangalore
Bangalore (IDSN)
Biak (BI1)
Brunei (BRU)
Lucknow (LK1)
Mauritius(MAU)
Trivandrum (TRV)
Port Blair

External Support

Alcantara
Cuiaba
HBK

DSN Stations

Madrid
Canberra
Goldstone



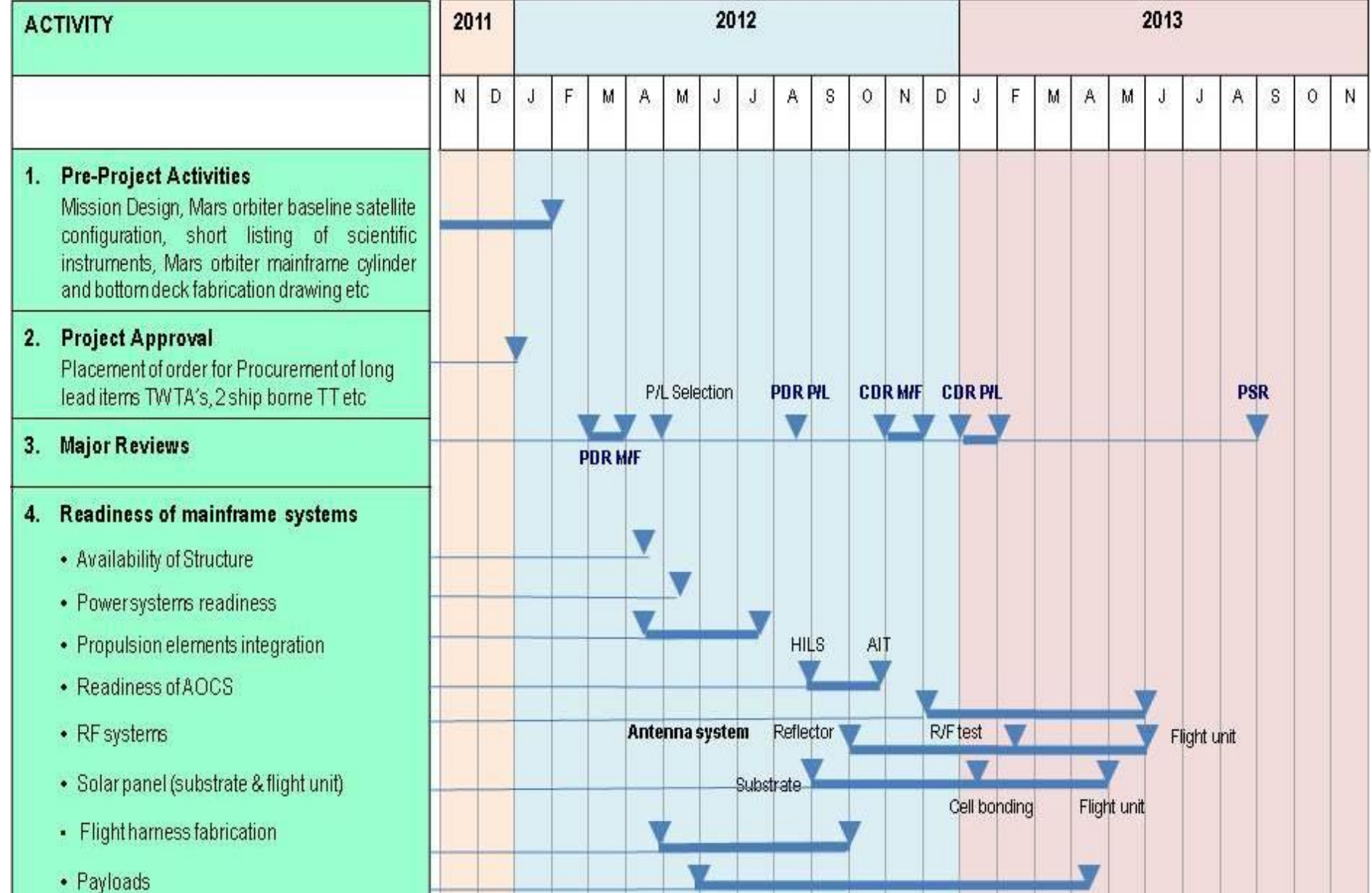
Mars Orbiter Mission- Flight Dynamics

Timeline of Various Phases

Phase	Period	No. of Days	Remarks
Earth Bound	2013 Oct 21 To 2013 Dec 3	44	• 6 LEB Operations • 58 Passes through Radiation Belt
Cruise (Helio-centric)	2013 Dec 3 To 2014 Sep 22	298	• TCM#1 on 2013 Dec 11 • TCM#2 planned around mid of Cruise Phase • TCM#3, #4 during (MOI-1) month
Martian	2014 Sep 22 Onwards	Till end of Mission	• MOI on 2014 Sep 24

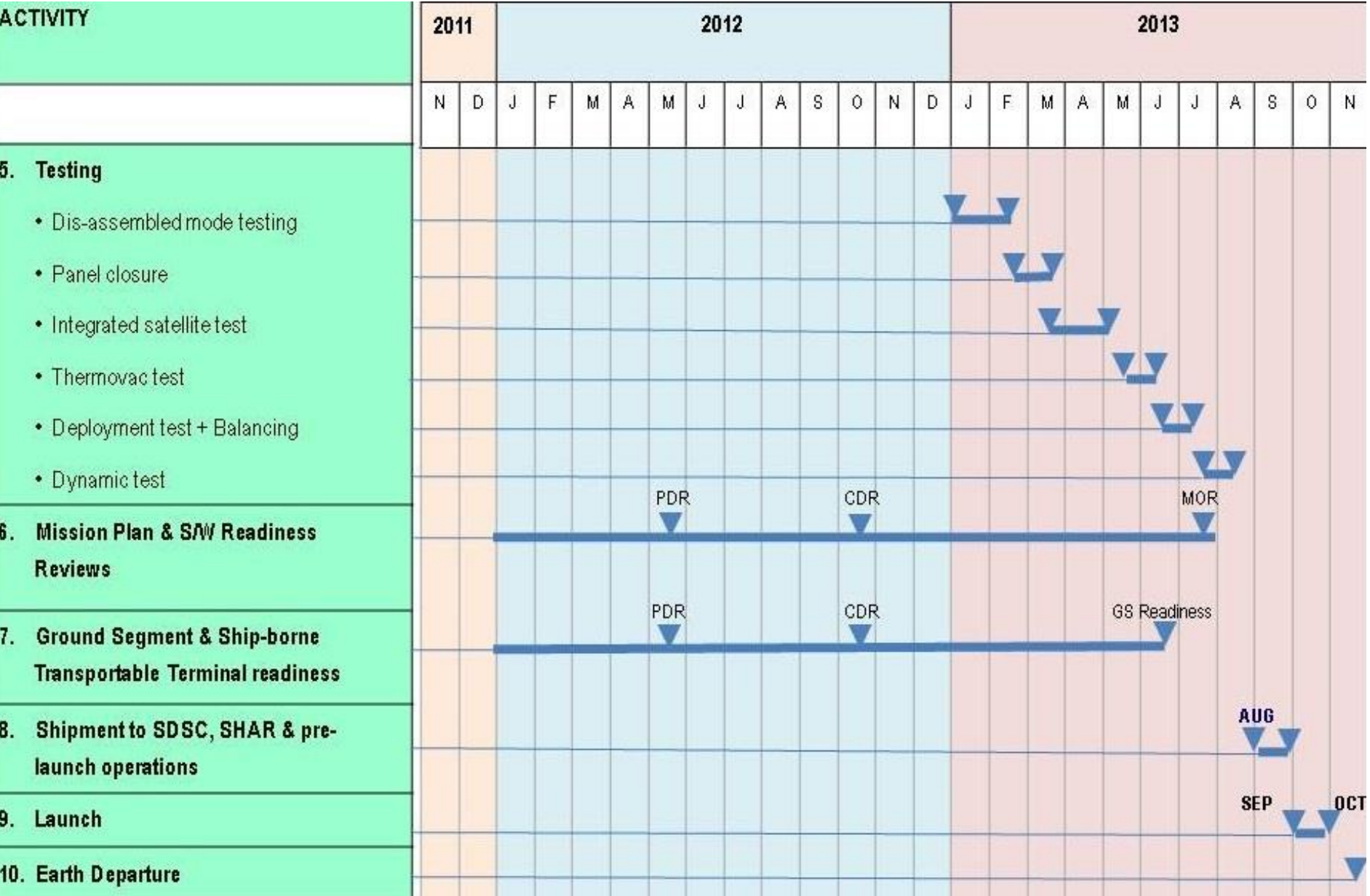
Mars Orbiter Mission- Project Management

Planned Schedule



Mars Orbiter Mission- Project Management

Planned Schedule



Mars Orbiter Mission- Project Management Challenges

- To realize a satellite in quick turn around time
- Launch opportunity : once in 26 months. If September 2013 target is missed, next only in January 2016.

Best Practices

- - **Use of flight proven Mainframe subsystem:** The spacecraft was configured with the right mix of design from flight proven IRS/INSAT/Chandrayaan-1 bus. Improvisation required for MOM were in the area of propulsion system, power system, communication system, onboard autonomy and thermal control system
 - **Micro Level Scheduling:** Project schedules were continuously monitored and assessed, to effectively accomplish each of project milestone as per planned schedule. An online information system was developed to monitor, assess, and evaluate project realization at micro level of detail.
 - **Project Priority:** In view of constraint of launch opportunity, the project was given highest, project priority and all the resources were pooled to accomplish the mission
 - **Stringent Review Mechanism:** Stringent review mechanism and extensive review by 5 specialized HLRC, ADCOS, PSG, SSTRC, Internal Review played a vital role in Mars orbiter mission project management.

Mars Orbiter Mission- Project Management

Special Review Committee

1. High level review committee (HLRC) Chaired by Chairman ISRO for closely monitoring the progress of the project and effective decision making.
2. Advisory committee on space sciences (ADCOS) for identifying the scientific payloads chaired by Prof U R Rao, Chairman
3. Payload Steering Group (PSG) for ensuring the timely realization of scientific payloads chaired by Shri S Kirankumar.
4. Standing Scientific & Technical Review committee (SSTRC) for implementation of MOM including orbiter spacecraft, interface with LV, ground segment including network support and post launch operations chaired by Dr T K Alex,
5. Management of International Co-operation & Interfaces by Shri V Koteswara Rao, Scientific Secretary , ISRO HQ.

Mars Orbiter Mission- Lesson learnt

1. Studied all International Mars Missions including mission approach for Orbiter, Lander, Rover and fly by missions.
2. Out of 51 attempts to reach the planet, only 21 succeeded, a success rate of 42%. Eighteen of the missions included attempts to land on the surface, but only eight transmitted data after landing.
3. The majority of the failed missions occurred in the early years of space exploration and were part of the Soviet and later Russian Mars probe program that suffered several technical difficulties,
4. The reasons for the failures were not connected with MARS hostile conditions. Majority of failures are primarily due to Launch related issues followed by propulsion system problems, landing problems, software errors both in ground and on-board, Human errors, insufficient hardware testing and the conceived mission concepts.

Mars Orbiter Mission Realization: A Glance

Milestone	Actual Schedule	Planned Schedule
Configuration finalization	July 2012	Jan 2012
Structure Delivery	Jun 2012	April 2012
Preliminary Design Review	21 September 2012	April 2012
Budget Approval	20 October 2012	Dec 2011
Pre- Shipment Review	21 September 2013	Aug 2013
Launch	5 November 2013	October 2013
Mars Orbit Insertion	24 September 2014	September 2014

MOM was realized in a record time of 15 months

Conclusion

- Technology challenges were taken up on top priority
- Micro level planning and scheduling was the key towards the success
- Multi level review mechanism was the catalyst
- Concurrent and collaborative engineering efforts from all ISRO Centres
- Thoroughly analyzed the lesson learnt from other Mars Missions
- Use of heritage systems
- Dedicated team effort
- Launch window was frozen before the project was conceived.

