2025 제 10 회 초소형위성 워크샵

Presentation [1-1]

Methodology of system design and sizing for L4 Spacecraft

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System design and sizing for L4 Spaceship

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System design and sizing for L4 Spaceship

L4 Mission Overview

L4 Mission

L4 Mission Success Strategy

The development of payload technologies, spaceship development technologies, and the Integration of data management systems will drive the success of the L4 solar observation mission

Executing strategic scientific mission through solar observation

Spaceship Development	Strategy
1. Development of scientific payloads to secure solar observation data	Development of precision remote observation sensors for solar activity
	Development of equipment for in-situ observation of energetic particles and magnetic fields
	Development of data transmission equipment using deep space optical communications
2. Orbit design and development of domestic spaceship for solar exploration	Establishment of a mission-oriented satellite system design
	Development of satellite platforms for operate in the L4 environment
	Ensuring mission reliability through satellite integration and testing
	Mission specific orbit design and selection of launch vehicles

DSN Infrastructure	Strategy
3. Establishment of a data management system for space observation	Establishment of an NRT science data transmission system
	Development of data-based mission operation and simulation technologies

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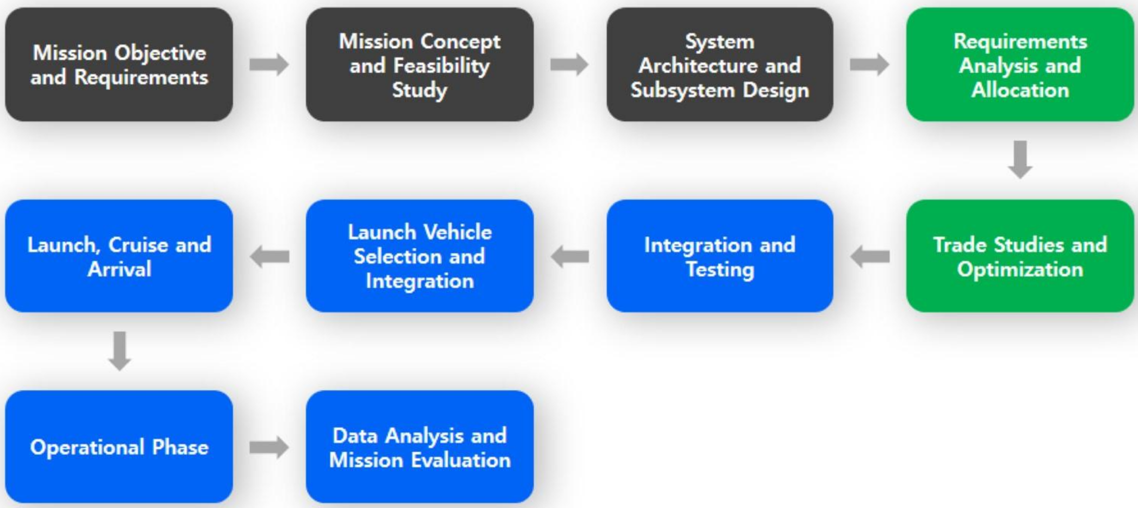
System Design and sizing for L4 Spaceship

Design Approach

L4 Mission Spaceship Development Roadmap

Spaceship Requirements flow down

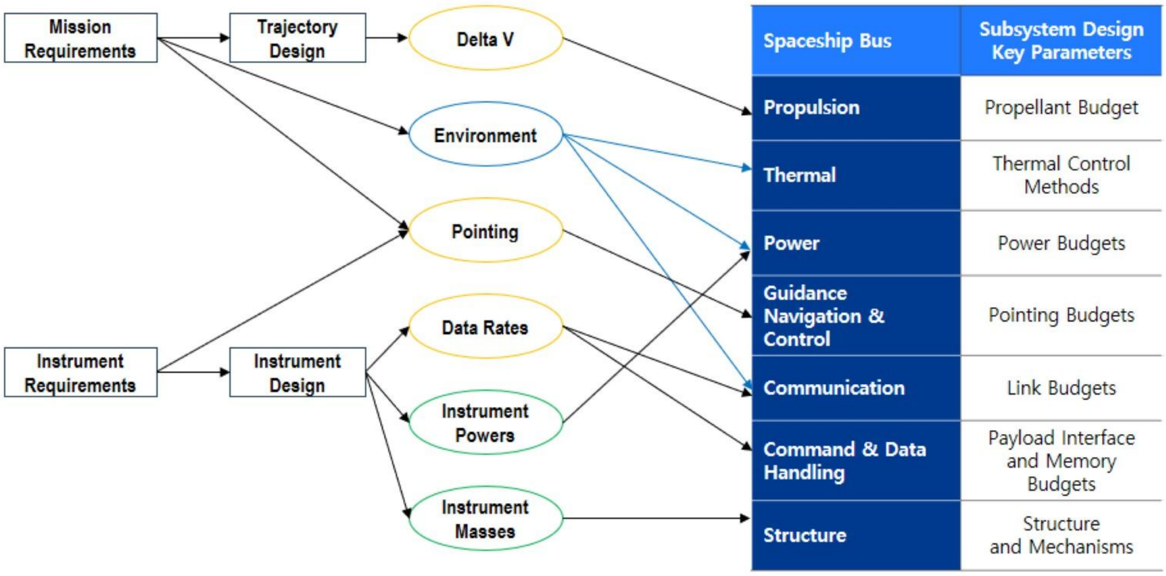
- Develop a mission concept and conduct a feasibility study to determine if the mission objectives are achievable within technical, budget, and schedule constraints
- System architecture and initial subsystems design are completed
- Requirements analysis and allocation are on-going



L4 Mission Spaceship Design Influence

System Design Influence Diagram

- Initial Bus subsystems design and sizing flow diagram



Specification of payload

Payload Type	Payload Name	Dimensions (L x W x H) (cm)	Mass (kg)	Power (W)	Data Rate (kbps)
Remote Sensing	Photospheric VMG (Vector Magnetograph)	70 x 40 x 50	33	62	182.04 (threshold), 45.51 (NRT)
	H-alpha Imaging Spectrograph	70 x 40 x 50	33	62	545.0(threshold), 109.23(NRT)
	EUV Imager	70 x 20 x 20	30	35	163.84(threshold), 54.61 (NRT)
	WL (White Light) Coronagraph	90 x 50 x 50	22.1	14.2	54.61 (threshold), 13.65 (NRT)
	Heliosphere Imager	60 x 40 x 50	16.5	13.5	91.02 (threshold), 22.76 (NRT)
	X-ray Spectrometer	30 x 30 x 30	15	15	12.50 (threshold)
In-Situ Instruments	Fluxgate Magnetometer	300(boom)x10x15	2*3.0	13	0.38 (threshold), 0.02 (NRT)
	Search Coil Magnetometer	300(boom)x24x24	5	1.4	24.00 (threshold), 48.00 (NRT)
	Radio/ Plasma Wave Detector	650cm Antenna (1.5cm radius)24x21x15 e-box	3*4.5	18.07	16.63 (threshold), 0.63 (NRT)
	Solar Wind Plasma Analyzer (SWPA)	28x18x23 31x12x24	2*3.5	23	10.24 (threshold), 0.22 (NRT)
	High Energy Particle Detector (HEPD)	50x30x15	5	7	0.09 (threshold), 1.33 (NRT)
	Radiation Monitor (RM)	27 x 27 x 27	7	9	3.03 (threshold)
	Dust Detector	30 x 30 x 30	12.5	25	11.57
Total			188.3	255	1332.2 kbps [RS]+ 41.32 kbps [In-Situ] (threshold)

Remote Sensing Payloads

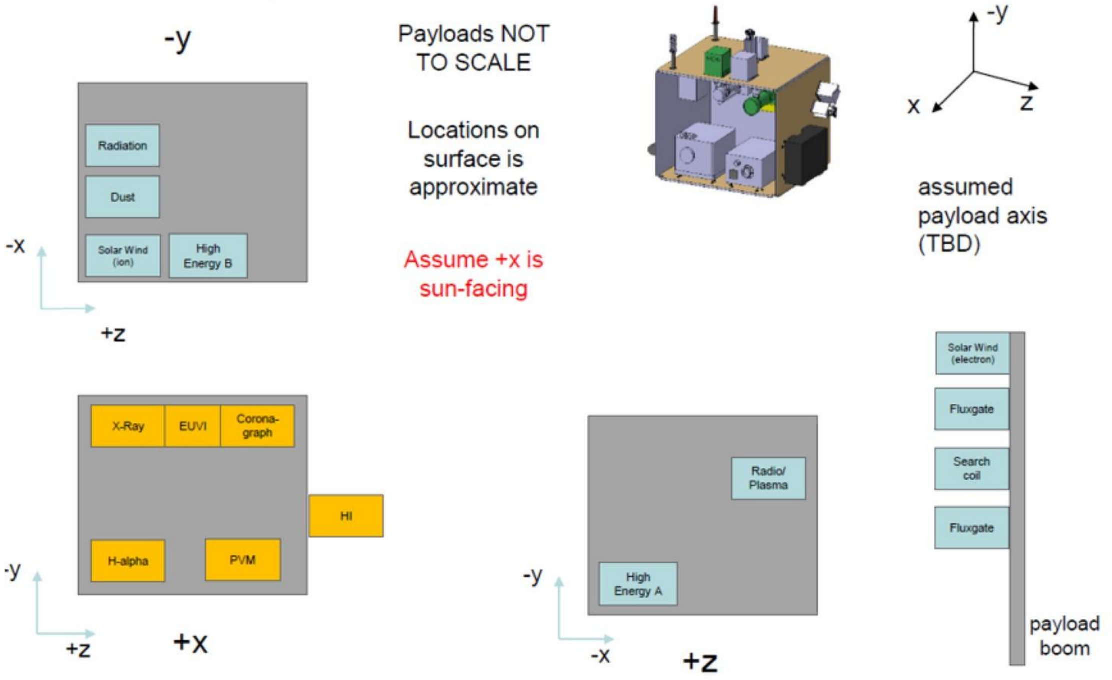
구분	No.	Payload Name	Payload Description	Payload Layout Consideration
Remote Sensing	1	Photospheric VMG (Vector Magnetograph)	• Observation of the photospheric magnetic field • Provides data for studying the following phenomenon – Magnetic drivers of solar eruptions – Characteristics of solar regions that produce solar energetic particles – Origin of magnetic switchback events and high speed turbulent solar winds	• Optimal placement for solar observation
	2	H-alpha Imaging Spectrograph	• Provides data for studying pre-eruptive signatures of flare or CMEs in the low low atmosphere	• Optimal placement for solar observation
	3	EUV Imager	• Observation of inner coronal signatures to inspect 3D EUV structure in the corona • Provides data for understanding coronal heating and solar wind acceleration, as well as various coronal structure, structural changes and corona vibration	• Optimal placement for solar observation
	4	WL (White Light) Coronagraph	• Observation of Sun's outermost layer, corona • Provides data for observation of 3D stereoscopic features and kinematics of CME, and their relationship with solar energetic particles(SEPs)	• Optimal placement for solar observation
	5	Heliosphere Imager	• Measurement of the Line-of-sight density and 3D structure of CMEs. • Accurate observation of the CME expansion, deflection and interaction with solar wind features	• Optimal placement for solar observation • Payload field of view (FOV)
	6	X-ray Spectrometer	• Detection of solar flare activities and their strength • Provides data for studying relationship between solar flare CME	• Optimal placement for solar observation

In-situ Payloads

구분	No.	Payload Name	Payload Description	Payload Layout Consideration
In-Situ Payloads	1	Solar Wind Plasma Analyzer (SWPA)	• Observation of structure and dynamics of high-speed and low-speed solar winds • Gives insight on the source and evolution of solar wind turbulence, as well as mechanism for solar wind acceleration and heating	• Optimal placement for Park Spiral Line observation, off-ecliptic observation along Parker Spiral Line • Payload field of view (FOV)
	2	High Energy Particle Detector (HEPD)	• Provides data for observing high speed particles of solar wind and CME and high energy particle phenomenon	• Optimal placement for Park Spiral Line observation, off-ecliptic observation along Parker Spiral Line • Payload field of view (FOV)
	3	Fluxgate Magnetometer	• Provides insight on magnetic connection between corona and solar wind, CME structure within solar wind, and magnitude of interplanetary shock caused by CME	• Installed on the boom that deploys to the opposite side of the Sun • Fluxgate-fluxgate-search coil configuration every 1 meter
	4	Search Coil Magnetometer	• Provides insight on magnetic connection between corona and solar wind, electromagnetic plasma wave characteristics in interplanetary magnetic field	
	5	Radiation Monitor (RM)	• Observation of high energy proton fluxes for monitoring of space radiation	• Optimal placement for solar observation
	6	Radio/Wave Detector	• Solar radiation(CME) flux measurement • Deep space radiation environment and effect	• 3-axis deployment boom for frequency characteristic and k-vector measurement • External structure/components such as antenna and solar array must be placed to avoid physical interference with boom deployment
	7	Dust Detector	• Observation of vertical zodiacal dust cloud structure and interstellar dust variation	• Placed to observe in the direction of spacecraft's flight (+Y dir. in spacecraft local coordinate system)

In-situ Payloads

Remote and In-situ Payload Orientation



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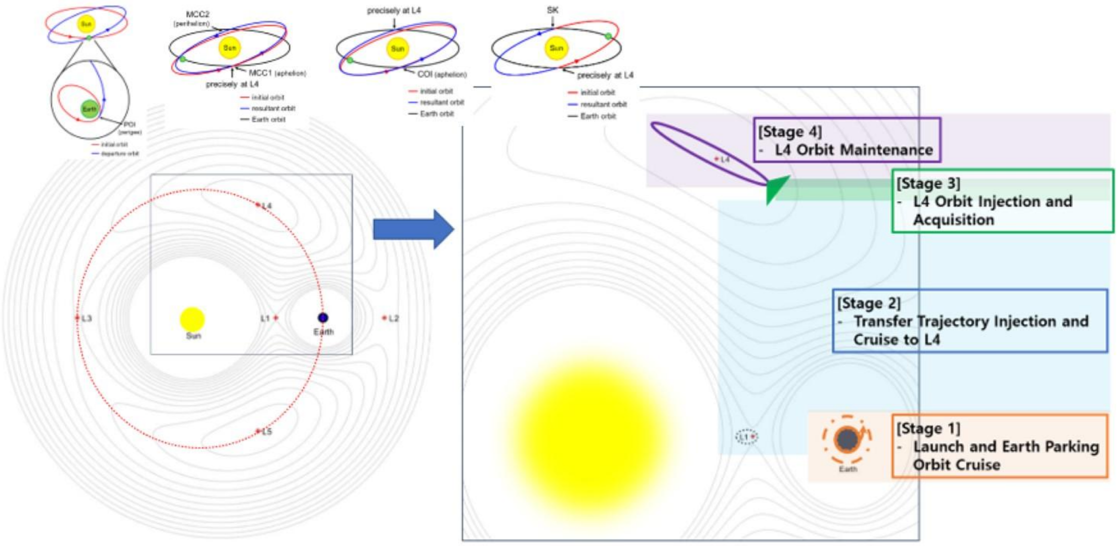
System design and sizing for L4 Spaceship

Initial Design Results

L4 Mission Design – Earth to L4 Point

L4 Spacecraft would be delivered by the Launch Vehicle directly into an Earth escape trajectory

- ▢ Stage 1 : Launch to Phasing Orbit Insertion (POI)
- ▢ Stage 2 : Midcourse Correction 1&2 (POI to Orbit Injection)
- ▢ Stage 3 : Circular Orbit Insertion (COI) to Inclination & Acquisition
- ▢ Stage 4 : Station Keeping (SK) to Science and Maintenance

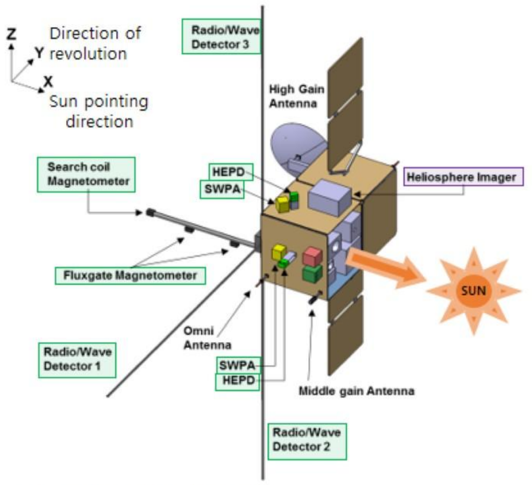


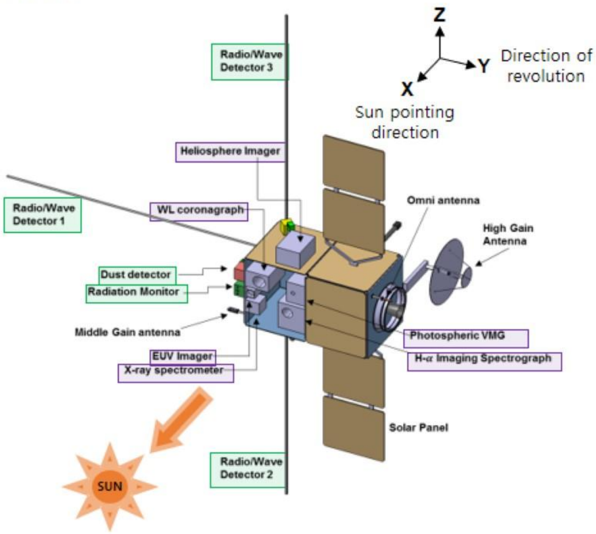
L4 Mission Design – at L4 Point

L4 Spacecraft Mission Operation Concept Define

▢ : Remote Sensing
▢ : In-situ Instrument

- ▢ Spacecraft observes with all instruments 100% of the time
- ▢ Spacecraft returns all science data on at least a daily cadence





※ Spacecraft Local Coordinate System
- Origin: Center point of Spacecraft-LV adapter plane
- X-axis: Sun pointing direction
- Y-axis: Direction of revolution
- Z-axis: Orthogonal to XY plane

System Design – Power Mode

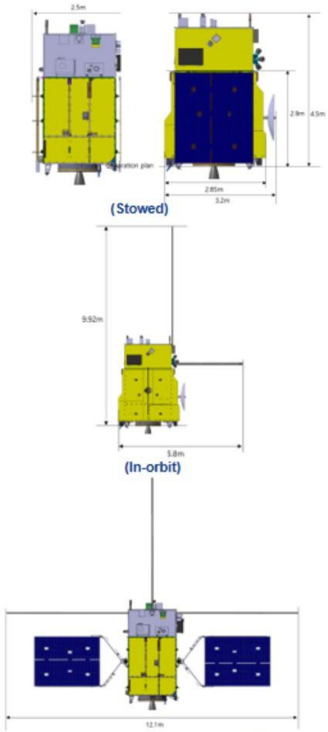
L4 Spacecraft Power Mode Define

- Telecom has all S-band, X-band and Optical communication

발표시 표출

Initial Design for L4 Mission

Platform Name	L4 Spaceship
System	Planetary
Total Platform Mass (Dry / Wet) (kg)	1870 / 2735
Platform Dimensions L x W x H (m)	S/C: 3.2 x 2.5 x 4.5(Stowed) S/C: 5.8 x 12.1 x 9.92(In-orbit)
Radiation TID (krad)	Less than 10 years GEO operation (TBD)
Design Lifetime (months)	2 years transfer, Over 6+3 yrs operation
Payload	
Available Payload Mass (kg)	250
Available Payload Power (W)	380
Payload Max Data Rate (Mbps)	78 Gbits (2:1 compression; 30% overhead applied)
ACS	
Pointing Control (arcsec)	45 arcsec, (half-cone 3-sigma)
Pointing Knowledge = Residual pointing error?	1 arcsec (half-cone 3-sigma)
Pointing Stability = Pointing drift errors?	0.12 arcsec (for 10 msec, half-cone 1-sigma), 10 arcsec (for 60 sec, half-cone 3-sigma)
Stabilization Type (3-axis, spin, gravity grad.)	3-axis stabilized
CDS	
Max. Payload Data Rate (Mbps)	X band : 86.4Gbits = 3Mbps * 8Hour
Data Storage Volume (GBytes)	192 Gbyte
Telecom	
Band(s)	S-band / X-band and Optical
Antenna type, size, quantity, gimbaled? (Yes / No)	X-band : HGA (DSN) Deep Space Optical Comm (DSOC)
Uplink Rate (kbps)	2 kbps
Downlink Rate (kbps)	1.5625 mbps(TBD)
Power	
Articulated Solar Array? (Yes / No)	Yes (2kW~3 kW)
Battery (Wh)	4kWh~8kWh
Propulsion	
No. of Prop Systems	LAE 1ea (420N) / RCT 14 P/R (10N)
Type(s) of System(s)	Biprop Chemical (MMH/MON)
Total Delta V (km/s)	1.156

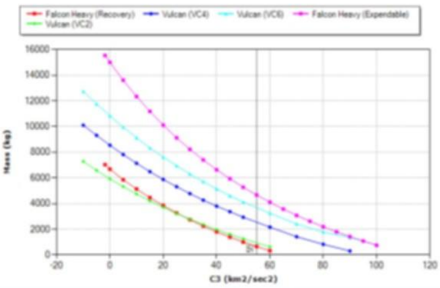


Initial Design for L4 Mission

Comparison MEL

- The table below compares the Team X MEL to the KAI-proved MEL, at the subsystem level
- Sufficient margins exist in total mass with MGA*(Mass Growth Allowance) of MEL
  - Predicted Spaceship mass is around 1870kg(Dry)/2,735kg(Wet)
  - Additional Propellant margin is 1,000kg in case of VC6

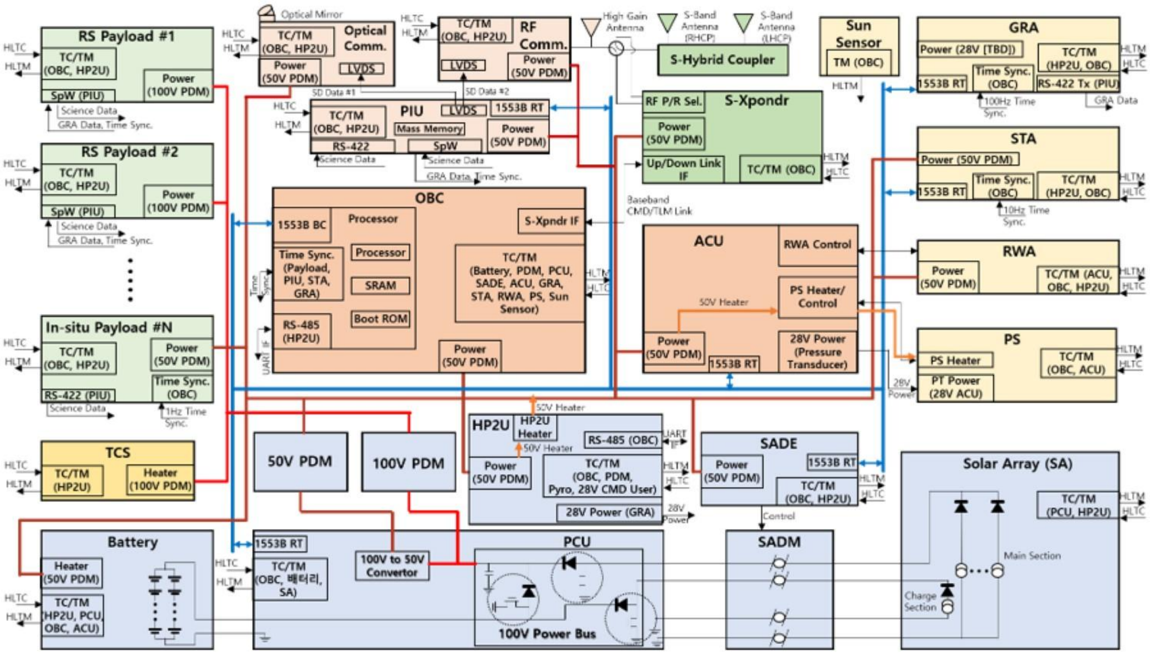
*Mass Growth Allowance (MGA) is used to account for expected growth in individual component masses as their designs mature, and is set on a component-by-component basis as a function of design maturity



발표시 표출

Initial Design for L4 Mission

Electrical Architecture (TBD)



Conclusion

- **This Conceptual design has been conducted to analyze Korean domestic spacecraft platforms' ability to accommodate all L4 mission payloads.**
- **The payload accommodation was arranged considering the requirements of 6 remote sensing and 7 In-situ instruments to study solar, heliospheric, and the L4 environment.**
- **Summary of Initial Design for L4 Spaceship**
  a. Launch would be on a heavy lift LV
  b. The spaceship uses bi-propellant propulsion only for main burns
  c. Sufficient margins exist in total mass, power, and data rate
- **Future Works**
  a. Improve the Pointing capability (Accuracy, Knowledge and Stability) of the spaceship
  b. The requirements for the PIU must be established, and the development concept (NRT and/or NCT Transmission) needs to be defined
  c. Development plans for HGA and Optical communication equipment must be established
  d. Spacecraft system design and component selection must be preceded by mission requirements and operation concept definition
  e. Further optimization and analysis that includes mission operation concept, system development requirements, payload design results will be conducted moving forward

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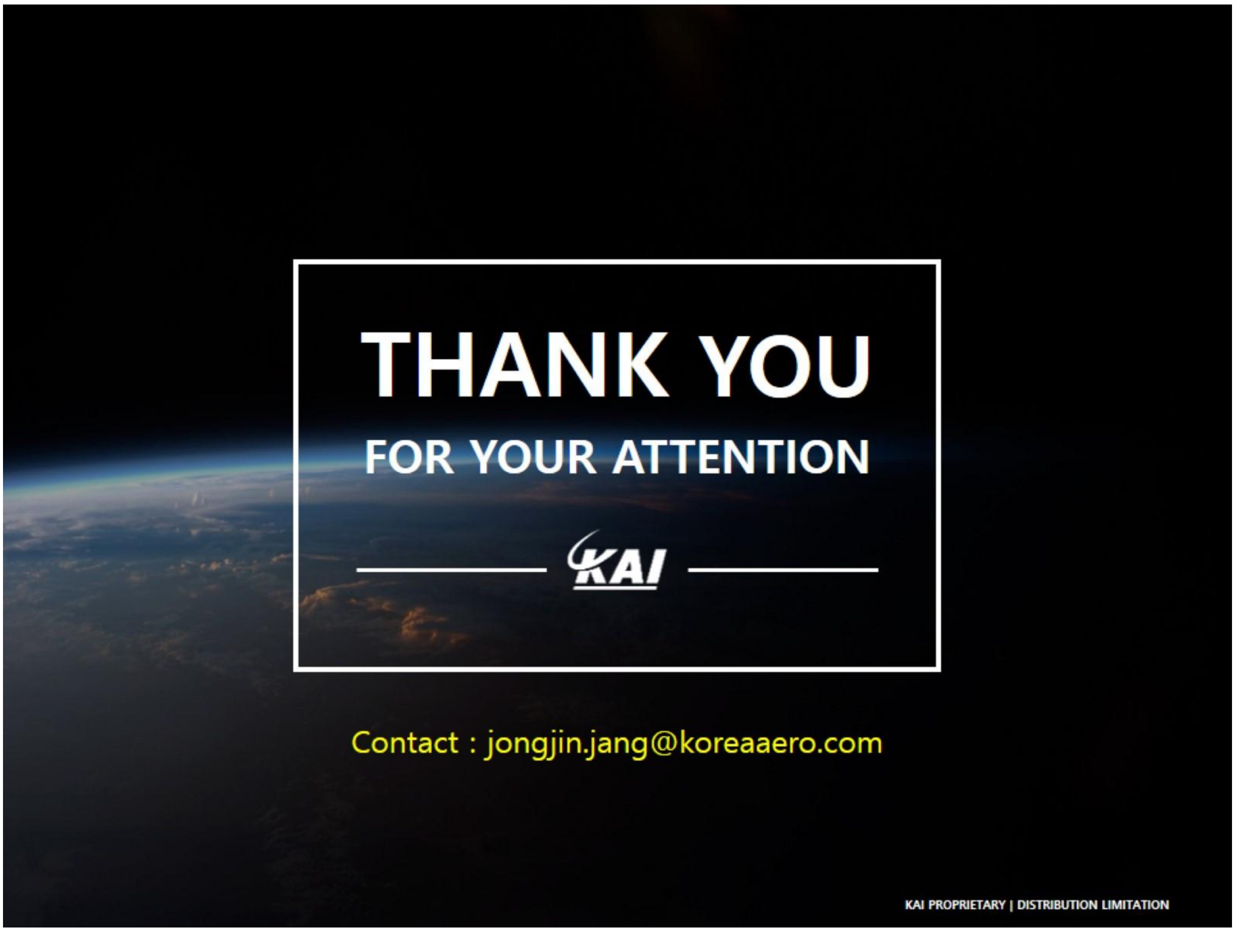
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