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Application of SE for the liquid propulsion system design of space launch vehicle

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Basic constraints for propulsion system

- Should be Liquid Propulsion System
  - Requirement for engine specific impulse
  - MTCR regulations
- Should use non-toxic propellant
  - Location of launch site
- Technical capability for engine development
  - Limitation to the thrust, specific impulse, etc.

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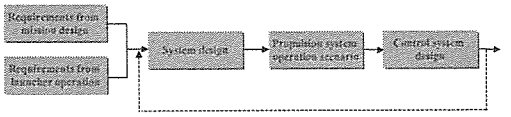
Development of system design concept

- Design flow chart



- Propulsion system IPT
  - Propulsion, structure, guidance & control, thermal, electronics

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System requirements

- Performance Requirements

	1st Stage PS	2nd Stage PS
Vacuum Thrust (ton)		
Vacuum Specific Impulse (sec.)		
Usable Propellant during Flight (Kg)		
Burning Time		
Restart Capability		
Tail-off Impulse Accuracy (ton-sec.)		
Throttling Capability		
Thrust Vector Control		

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System requirements

- Lift-off Requirements
  - Build-up of 1st stage engine thrust to nominal State
  - Accuracy : Within % of nominal value
- 1st Stage Shut-down Requirements
  - Burn to fuel and/or oxidizer depletion
  - Allowable remaining propellant at Shut-down :
    Within % of total propellant (Propellant Utilization : %)

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System requirements

- 1st & 2nd stage separation requirements
  - Fire in the Hole (FITH) Separation (2nd stage engine ignites before Separation)
  - Thrust level at Separation

	1st Stage	2nd Stage
Vacuum Thrust (ton)	>	>

  - Time to nominal state from ignition signal for 2nd PS : sec.
- 2nd Stage Shut-down Requirements
  - Command Shut-down (from NGU)
  - For back-up, Depletion burn Shut-down capability required (Propellant Utilization : %)

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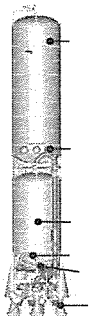
System layout of 1st stage PS

- 1st stage propulsion system (PS) consist of
  - Four (4) bi-propellant liquid engines:
    - Propellant : LOX + Kerosene
    - Pump-fed open cycle (bi-propellant GG)
    - Regenerative combustor cooling
    - Orifices for engine tune-up
  - Propellant feed system :
    - One oxidizer and one fuel tank
    - Pressurant tanks located
    - Propellant tank pressurization system
    - Pneumatic control system
    - No capability to control propellant feeding ra



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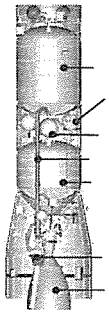
System layout of 2nd stage PS

- 2nd stage propulsion system (PS) consists of
  - One bi-propellant liquid engines:
    - Propellant : LOX + Kerosene
    - Pump-fed open cycle (bi-propellant GG)
    - Regenerative combustor cooling
    - Orifices for engine tune-up
  - Propellant feed system :
    - Oxidizer, fuel and pressurant tank
    - Propellant tank pressurization system
    - Pneumatic control system
    - Space purge system
    - No capability to control propellant feeding rate



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Consideration of PS operation scenario

- Launch preparation
  - On-board power
  - Fill pneumatic control tank & pressurant tanks
  - Low & high N2 purge
  - Fill oxidizer and fuel tank
  - Pre-pressurization of propellant tanks
- Ignition & Lift-off
  - 1st engine starting (starter, combustor & GG igniter)
  - Normal operation

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Consideration of PS operation scenario

- Stage separation (FITH)
  - 1st stage engine shut down & N2 purge
  - 2nd stage engine ignition
- 2nd stage operation
  - Normal operation
  - 2nd stage engine shut down & N2 purge

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Modifications

- Modification of system requirement for stage separation
  - Based on the PS operation scenario
  - Shut down characteristics of 1st stage engines
    - Requirement for the time and thrust level after shut down signal
  - Start up characteristics of 2nd stage engine
    - Requirement for the time and thrust level after ignition signal

Requirement Modification

: FITH → Cold separation with acceleration motor

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Modification

- Modification of PS design
  - To meet the system requirements for propellant utilization
    (% for 1st stage and % for 2nd stage)
  - Based on the PS operation scenario
  - Filling time for oxidizer tank
  - Variation of propellant consumption before lift-off
  - Heat addition to the oxidizer during launch (temperature rise)

Propulsion system design modification

: Introduce the tank depletion system with O/F and thrust control of engine

Conclusions

- **Necessity of propulsion system operation scenario on the system requirement generation**

  : Operation scenario could cause the modification of system requirements

- **Necessity of active propulsion system IPT**

  : To control interface problems
  : Especially, between the launcher mission design and propulsion system design at the system design phase