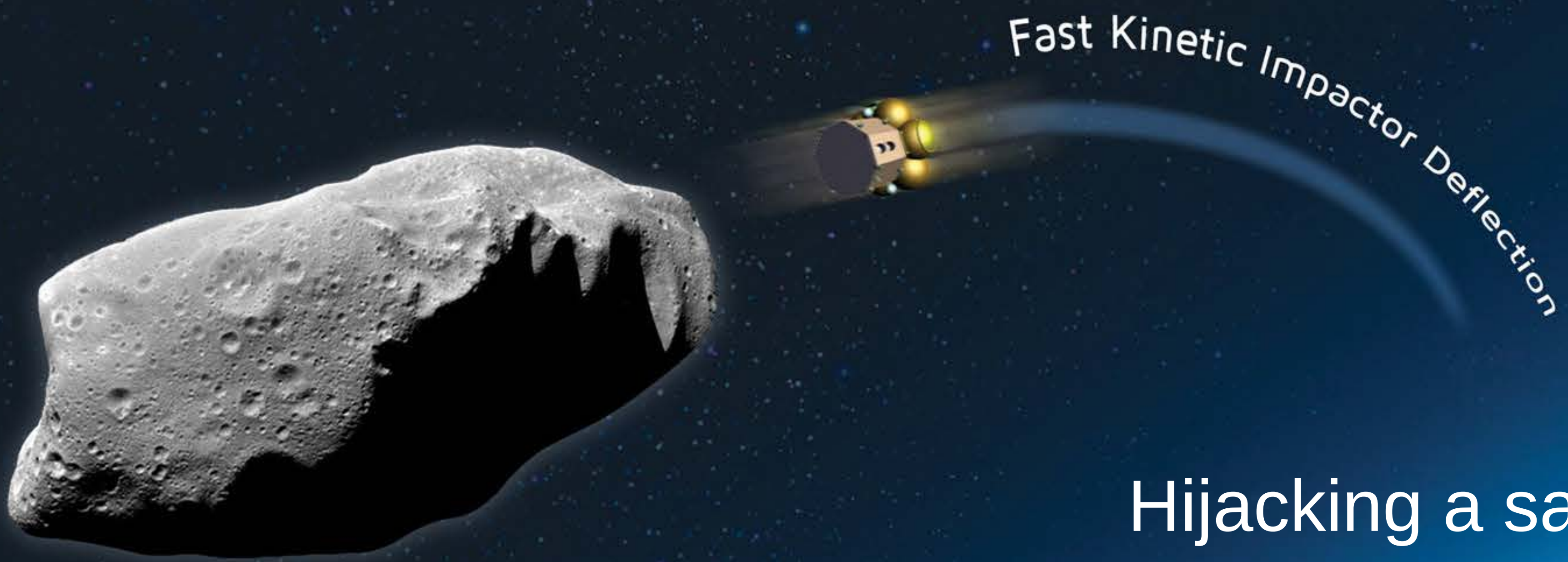

Hijacking a satellite for Short-Warning Asteroid Deflection – FastKD Mission, Design and Implementation

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Study objectives

Imagine an asteroid threat scenario, which is just discovered to impact Earth within 1-3 years from now!

What do we need to prepare to enable our Deflection Capabilities for short warning asteroid threats?

Study objective → **Assess the feasibility of modifying a commercial spacecraft platform in order to perform asteroid kinetic deflection in the shortest possible time**

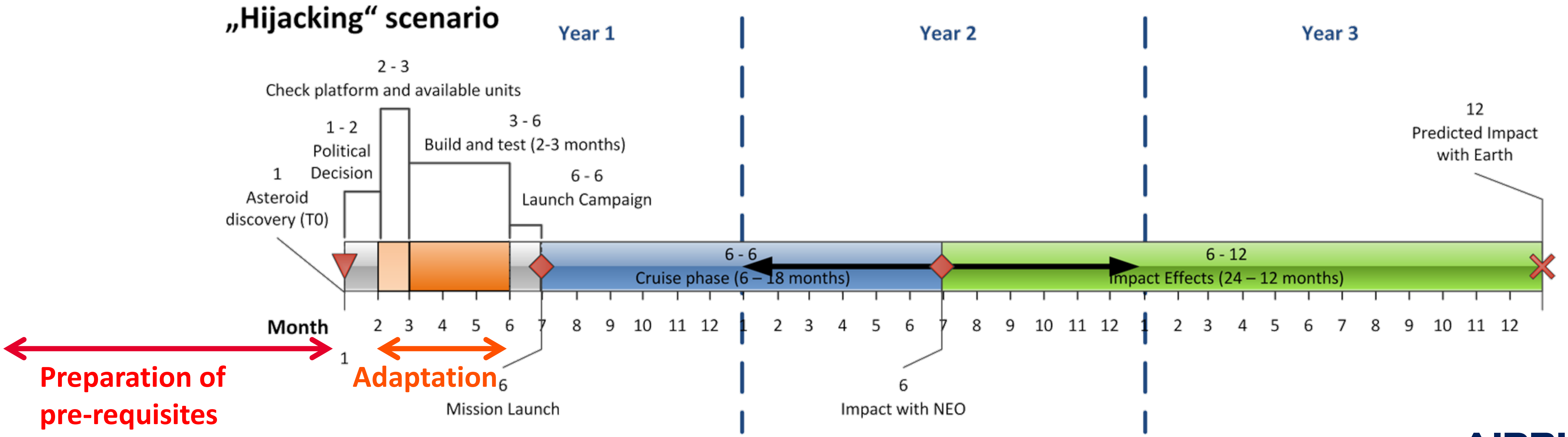
Driving requirement → Launch readiness within 6 months from threat discovery

Tasked to identify the

- needed pre-requisites,
- the platform capabilities,
- system requirements (with emphasis on GNC sub-system),
- minimal modifications & required activities to re-purpose a commercial platform,
- critical technology developments and long-lead items, and
- limitations of such an emergency kinetic deflection mission in terms of warning time and a priori knowledge.

Timeline of FastKD "Hijacking" Scenario

- Incoming asteroid is detected, analysis of the orbit propagation reveals a high probability of Earth impact in ~3 years
- Political decision makers push for rapid deflection attempt using KI technology
- Extremely constrained preparation time scenario with a **"to Launch" requirement of 6 months** or less
  → build/adaptation time of only 2-3 months
- Approach foreseen is to "hijack" an existing commercial platform already in build in integration facility and with minimal adaptations and additions convert to a kinetic deflection mission to achieve "best possible" deflection performance



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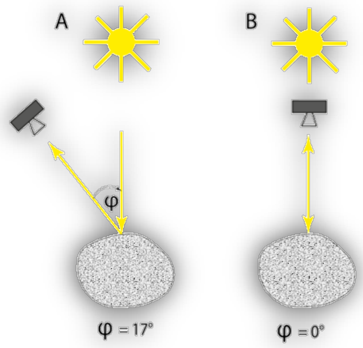
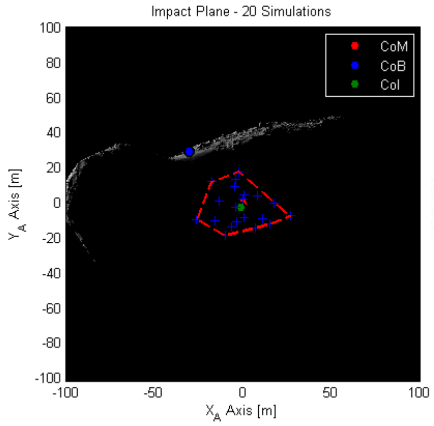
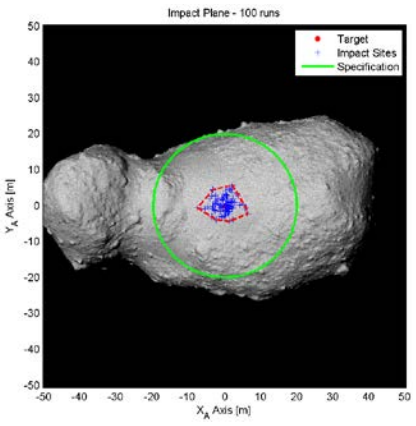
Mission Analysis

- …revealed the **deflection needs**, meaning the KD mission & system requirements to be met for successful asteroid deflection
- From all known NEOs: creation of a dedicated asteroid catalogue with NEOs in size range and close Earth encounters within next decade (252 objects D~20-80m, 45 PHAs included) → realistic asteroid threat scenarios
- Most relevant findings from trajectory analysis:
  - Deflection performance primarily depends on **early deflection** (short transfer time), impact impulse (mass*velocity), **relative Earth-asteroid geometry** and not so much on Impactor arrival mass.
  - For short warning scenarios: **higher allowed Solar Phase Angle** (SPA) at impact is required to achieve high deflection performance.
    And: SPA largely affects the launch opportunities: higher SPA results in many more feasible missions and thus increases the mission flexibility & deflection capabilities.
    → TIR NAC needed for greatest mission flexibility/applicability!
- 5 representative scenarios and deflection trajectories selected for more detailed Mission Analysis and requirements derivation.
  → Generic / Enveloping system design approach!



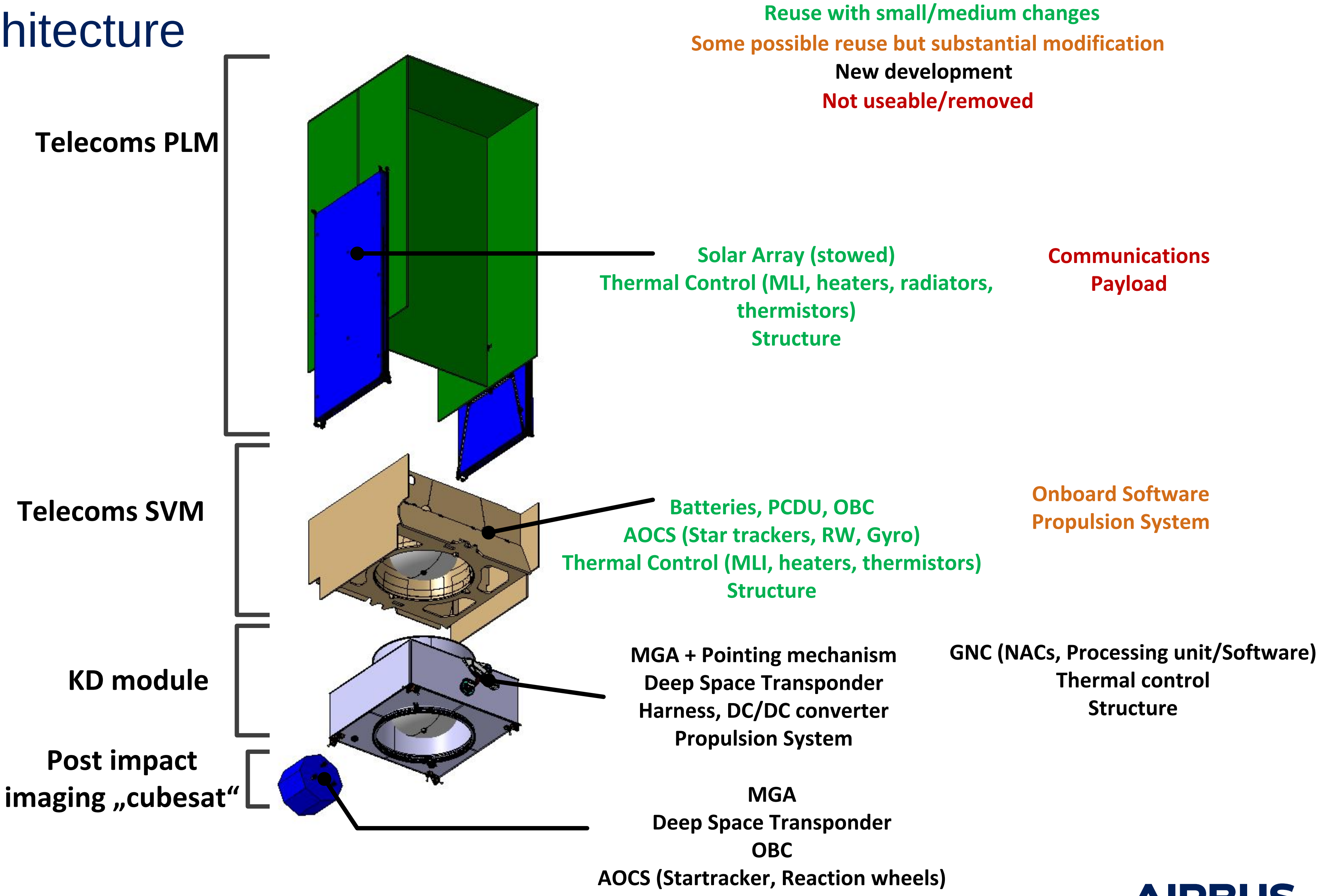




Impactor Design, Architecture

Survey of European platforms:
- identified availability & applicability for KD mission
- revealed need for “KD module” adding mission specific elements

Design Philosophy:
- Effort to minimise changes/adaptations and re-use platform „as is“
- “KD module” predeveloped as pre-requisite:
  - Contains all parts unique in nature (KI specific elements, lower TRL, pose higher risk of failure if not well developed and tested in advance (e.g. GNC, Software …)



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GNC

- Study performed extensive GNC analysis & design activities, supported by existing & reuse of tools developed in earlier projects
  - NEOShield-2: Tools and **Kinetic Impactor GNC design validated at TRL5-6**
    - Real-time compatible with space target
    - Tests done with COTS HW in the loop

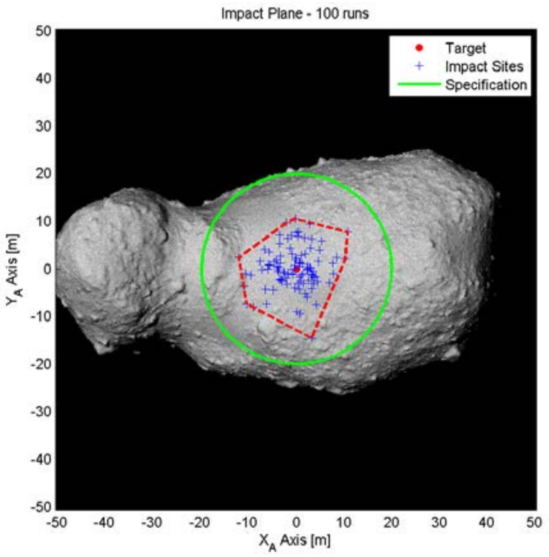
- Assessment of reusability of repurposed telecom platform equipment
  - Thruster type & configuration (thrust, mass & configuration; thruster errors relevance for changed NAC performances)
  - Sensors, OBC

- Assessment & proposal of GNC designs for 2 FastKD reference scenarios
  - **Targeting performance shown for Worst Case scenario**

- Sizing of Narrow Angle Camera suite, in particular TIR detector and its specification
  - Required because of potentially high phase angles & generally unknown asteroid shape
  - NAC is critical key technology & long lead item
    → feasibility study & development to be initiated ASAP

Worst Case scenario: 2015 JJ (100 cases)

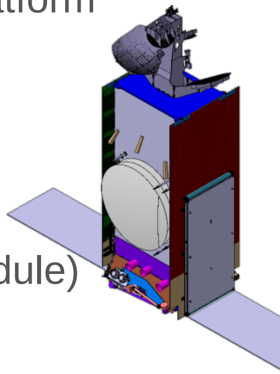
Parameter	Value
NAC FoV	0.5 degree
Thrust error	3 % (1σ)



Statistical Parameter	Results
Mean Accuracy (m)	5.4
Min Impact Error (m)	0.5
Max Impact Error (m)	14.8
Standard deviation (m)	3.2
Mean +3 sigma (m)	15.0
Control ΔV range (m/s)	5.3 - 8.9

Conclusions

- **A Fast Kinetic Deflection mission (with 6 months launch readiness) for short warning time asteroid threats is feasible!**
  - The FastKD activity identified:
    - the pre-requisites needed therefore and modification activities to **"hijack"** and re-purpose a commercial telecoms platform
    - critical key technologies and long lead items
  - Platform capabilities and limitations of such an emergency kinetic deflection mission are identified.



- A viable preliminary design solution is proposed and targeting GNC performance is successfully demonstrated
  - Largely driven by 6 months launch readiness → requires high efforts for pre-developments & pre-requisites (= KD module)
  - KD module to encompass all unique mission specific components not available/suitable on hijacked platform, primarily: GNC, Propulsion and Communication subsystems.

- Alternatives: Dedicated S/C or "Cherry Picking" scenario(*)

- To build up and establish European "Asteroid Deflection Capabilities" it is recommended to initiate as soon as possible
  - Corresponding FastKD Phase A design study and
  - NAC suite feasibility and subsequent development studies

	Stored dedicated spacecraft	"Hijacking" scenario	"Cherry Picking" scenario
Targeted launch readiness	Fastest (≤1 month)	Fast (6 months)	Medium (1-1.5 years)
Preparation efforts (even if no threat materializes)	**Highest preparation efforts:** Full dedicated S/C	**High preparation efforts** for needed pre-requisites: KD module	**Low preparation efforts:** Phase A/B1 design study + key technology development
Total implementation efforts	Medium S/C production costs + storage	Highest S/C production costs (KD module + Hijacked Platform + emergency adaptations) + storage	Medium S/C production costs, no storage

(*) "Cherry picking" scenario: Emergency reallocation of any suitable platform/hardware units from any European integration facility followed by fast-track AIT to build the KI spacecraft. S/C design and fast-track AIT to be extensively prepared in advance.

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Many thanks for your attention.

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