SMART SMALL SATELLITE SYSTEMS THALES IN NTU

Rendezvous & Docking With Uncooperative Targets

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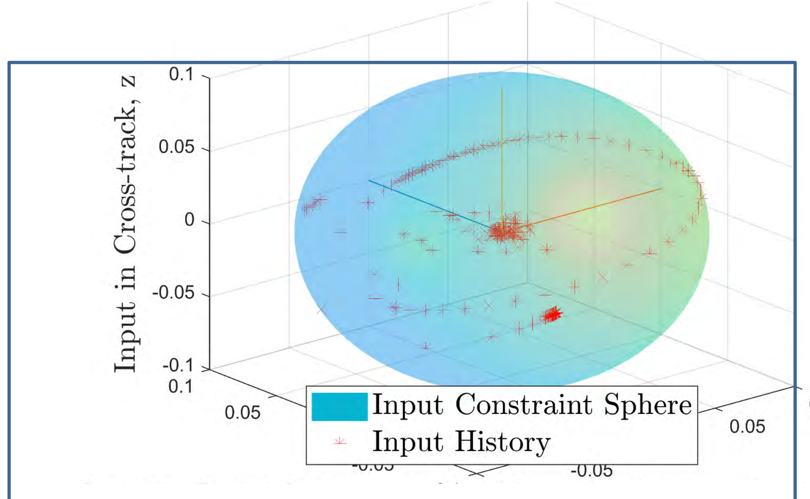
Introduction

Given two space vehicles orbiting a central body, the purpose of rendezvous and docking (RVD) is for two spacecrafts to reach predefined relative configuration in each other's proximity. RVD technology enabled historic space flights such as Manned Lunar Mission, International Space Station in orbit assembly, etc. In the future, use cases of RVD technologies will be further extended to autonomous space servicing operations and the main application fields can be listed as sample & return, In-orbit assembly, maintenance, refueling, capture and small asteroid explorations. Today, subset of autonomous docking missions have been achieved but none of them has achieved docking with an uncooperative target case.

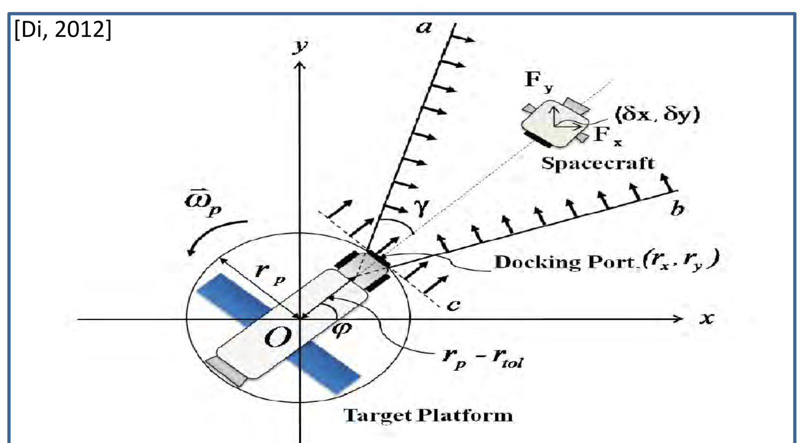
Objective

To develop guidance & control strategy for motion planning for rendezvous and docking with uncooperative targets

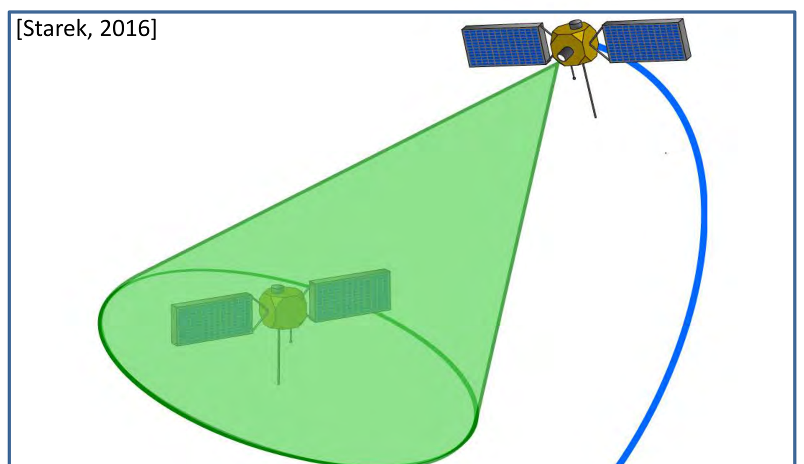
Main Challenge: Constraints Management



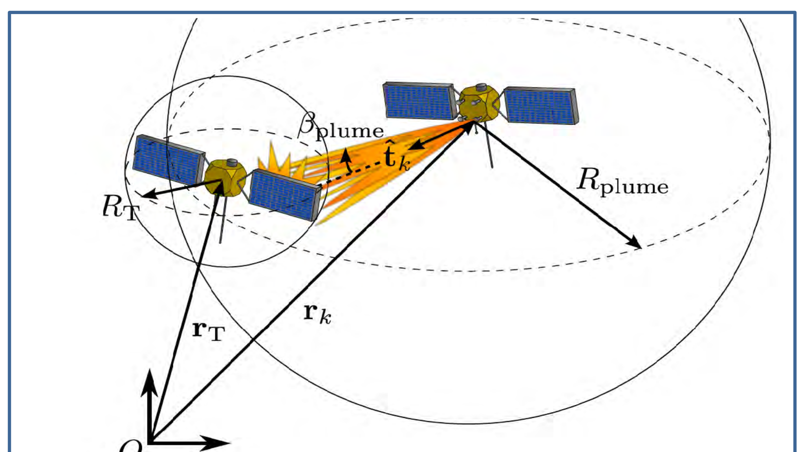
Physical: Realistic Inputs



Line Of Sight: Safe Approach



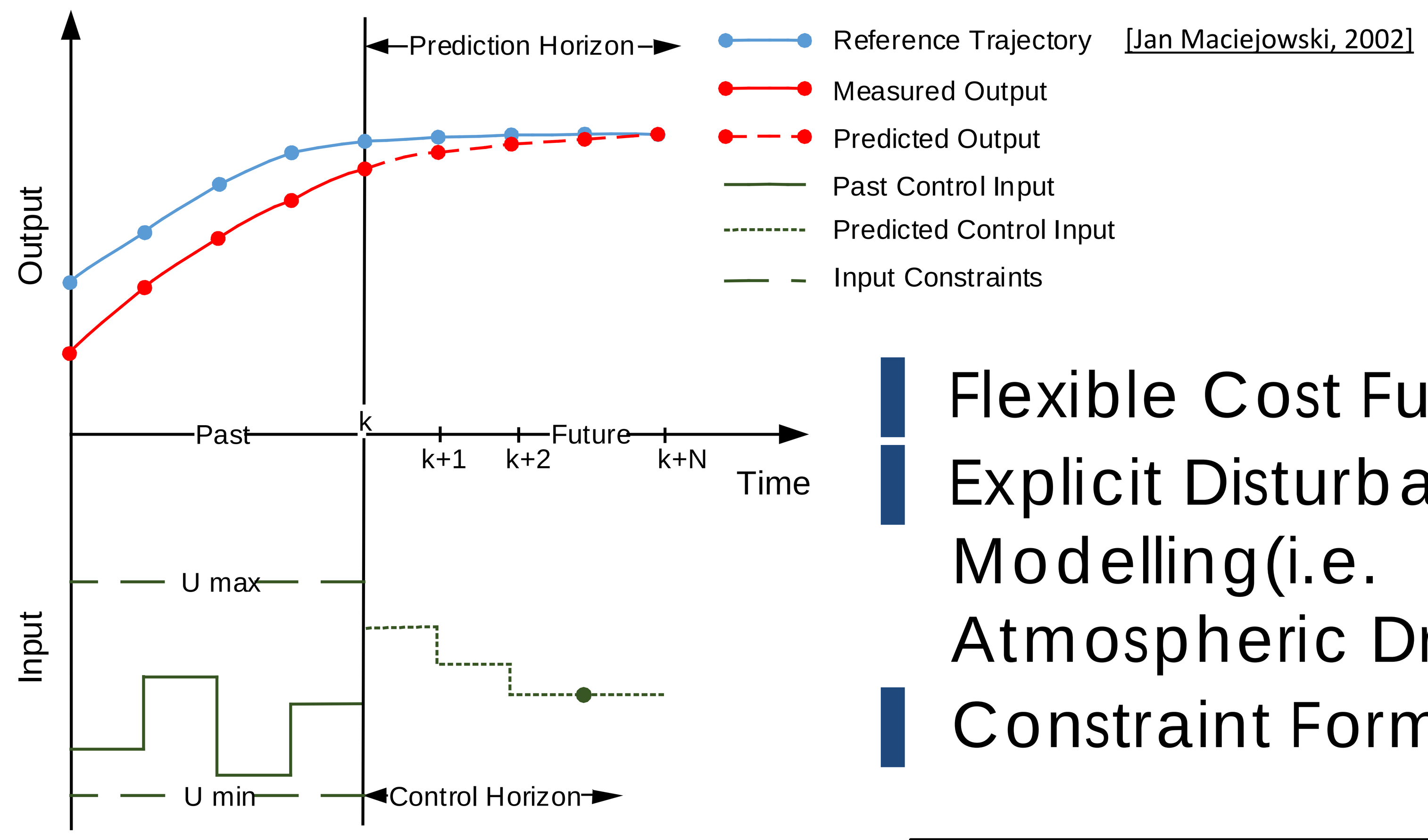
Field Of View: For Sensors



Plume Impingement

Proposed Framework

MPC to **generate a set of control inputs** and resulting predicted states to **optimize performance** objectives while respecting **constraints.**



- Flexible Cost Function
- Explicit Disturbance Modelling(i.e. Atmospheric Drag)
- Constraint Formulation

Formulation Of MPC

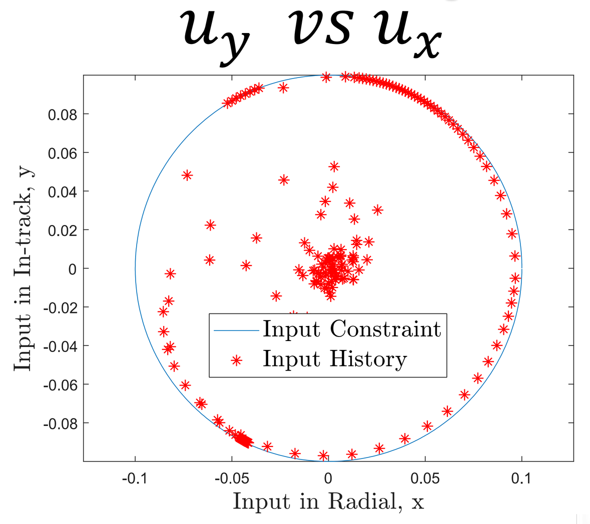
X: States (i.e. position)
U: Input (i.e. thrust force)

$$\textbf{minimize} \sum_{i=0}^{N-1} \left[X_{k+i|k}^T Q X_{k+i|k} + U_{k+i|k}^T R U_{k+i|k}\right] + X_{k+N|k}^T Q_p X_{k+N|k}$$

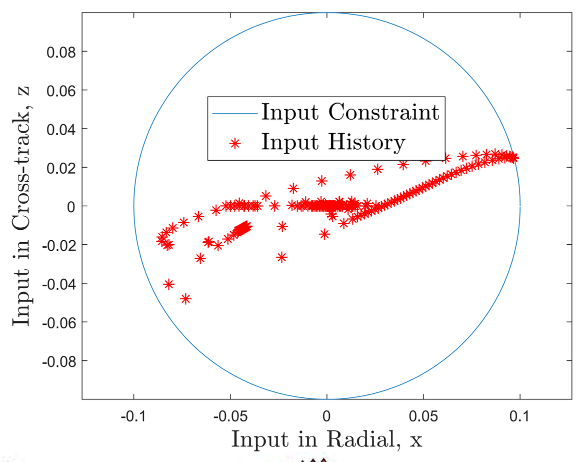
$$\textbf{subject to} \quad X_{k+1} = A_d X_k + B_d U_k,$$
$$X(k|k) = X_k,$$
$$\left(u_{x,k}^2 + u_{y,k}^2 + u_{z,k}^2\right) \le u_{max}^2, \forall\, k \in [0, N-1],$$
$$A_{LOS} X \le b_{LOS}$$

Results: Input History & State History

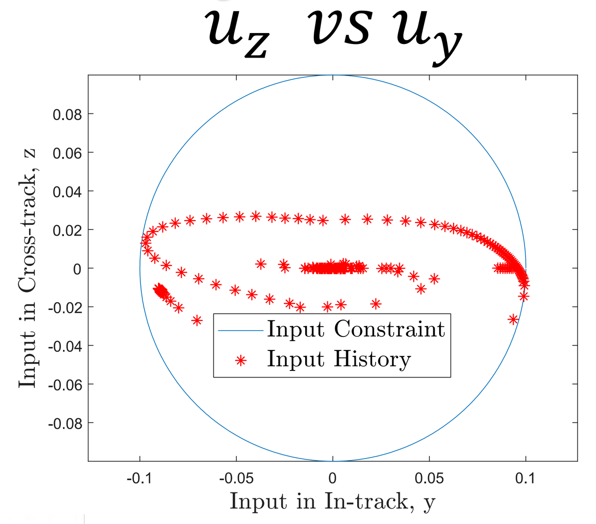
u_y vs u_x

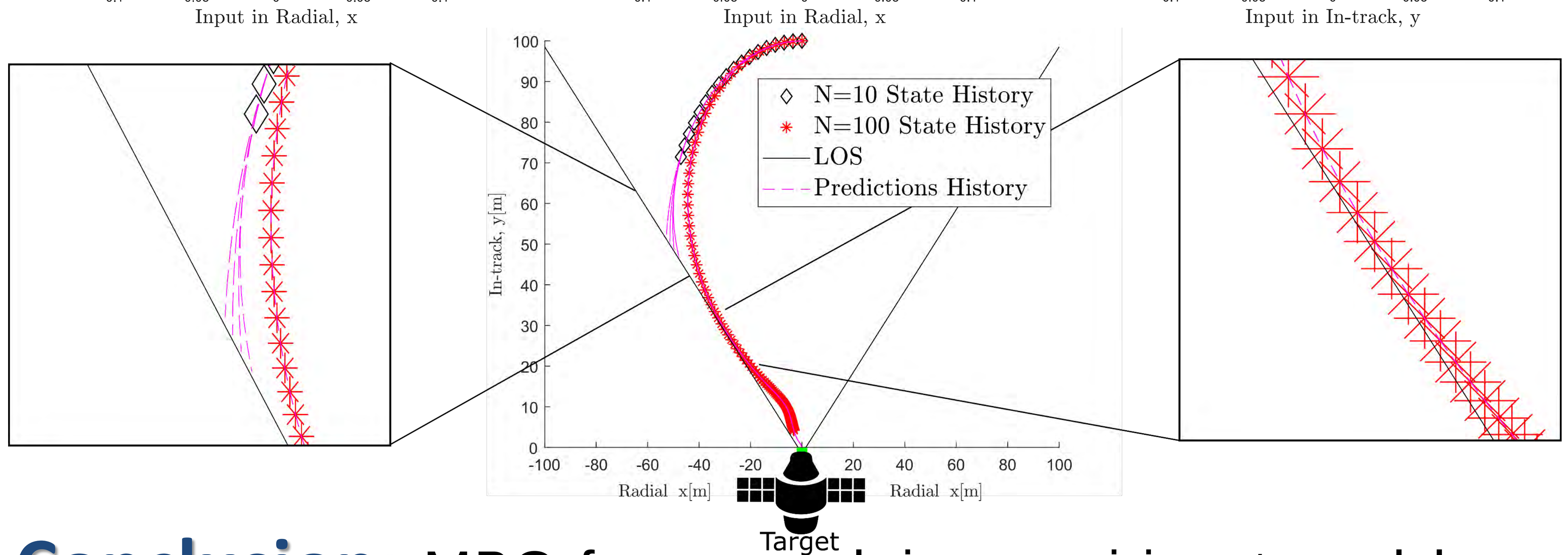


u_z vs u_x



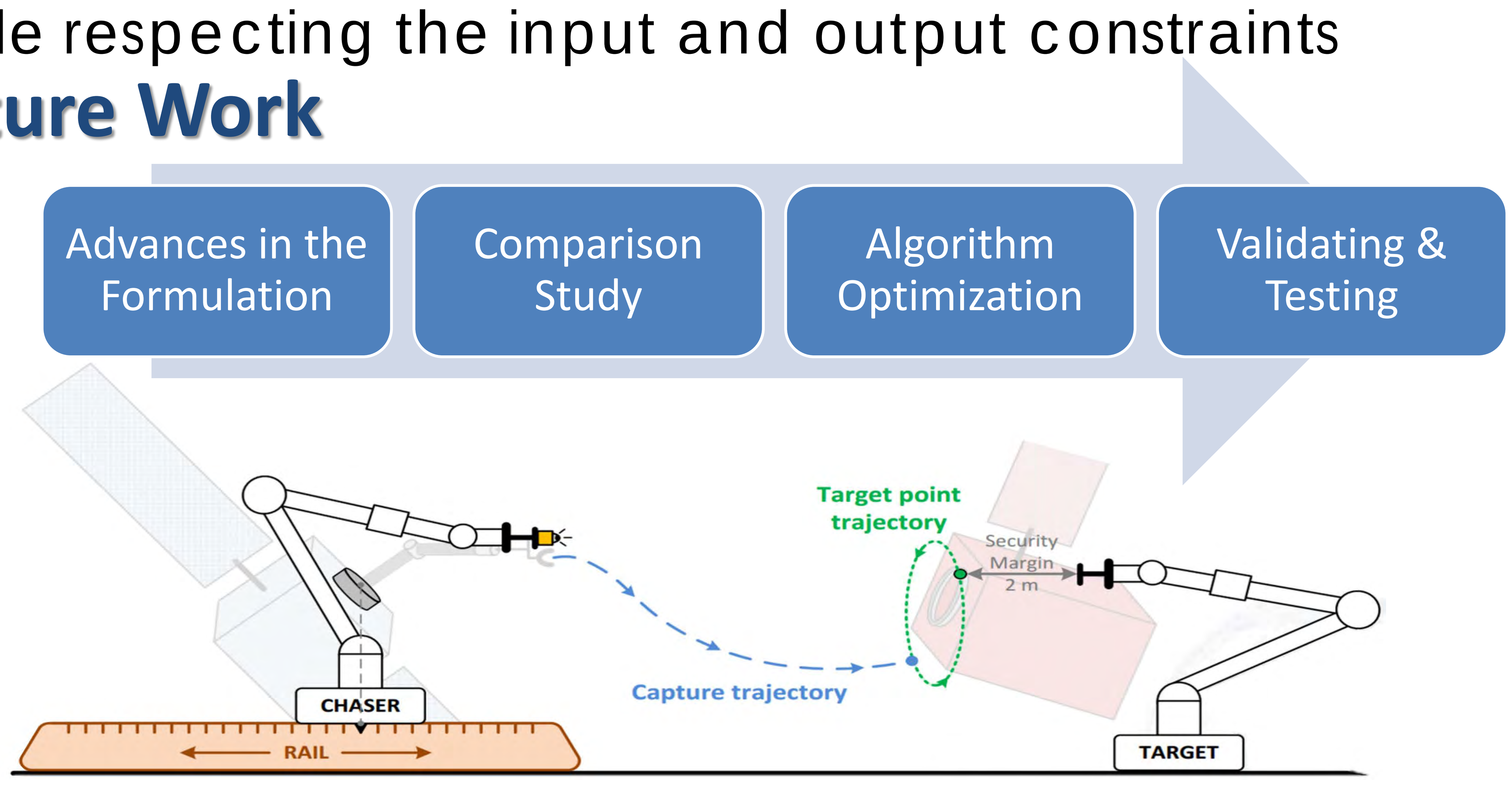
u_z vs u_y





Conclusion: MPC framework is promising to address RVD problem because it can achieve docking conditions with a tumbling non-cooperative target while respecting the input and output constraints

Future Work



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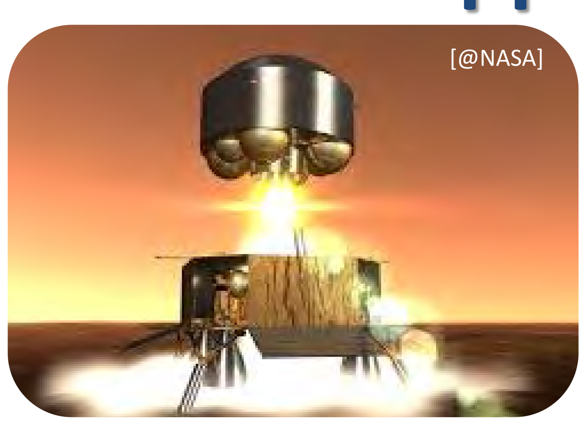
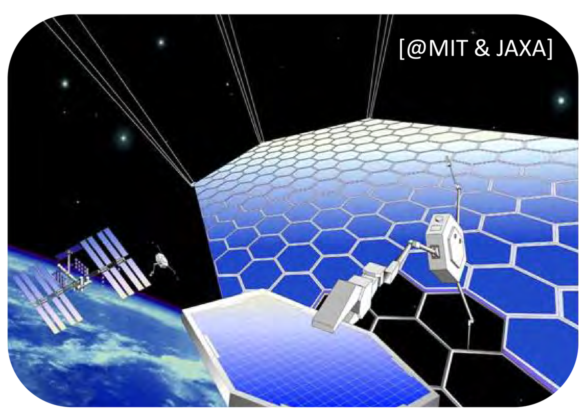
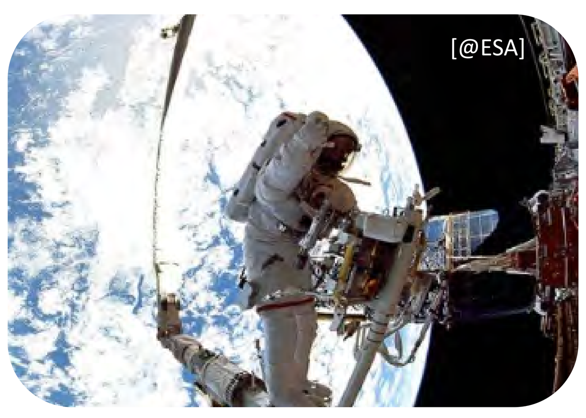
Potential Applications in the Future



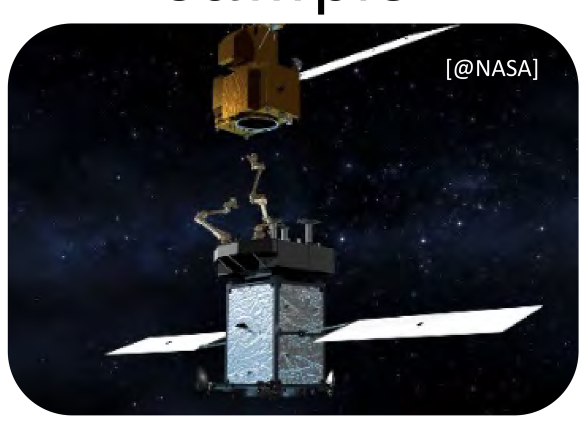
Sample



Assembly

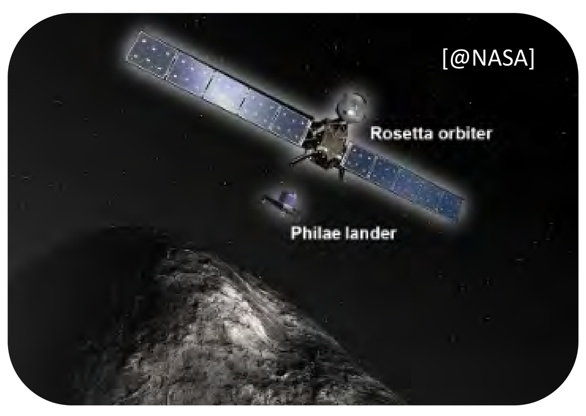


Maintenance



Re-Fueling

Capture



Small Asteroid Explorations

NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

ThalesAlenia Space — a Thales / Leonardo company

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