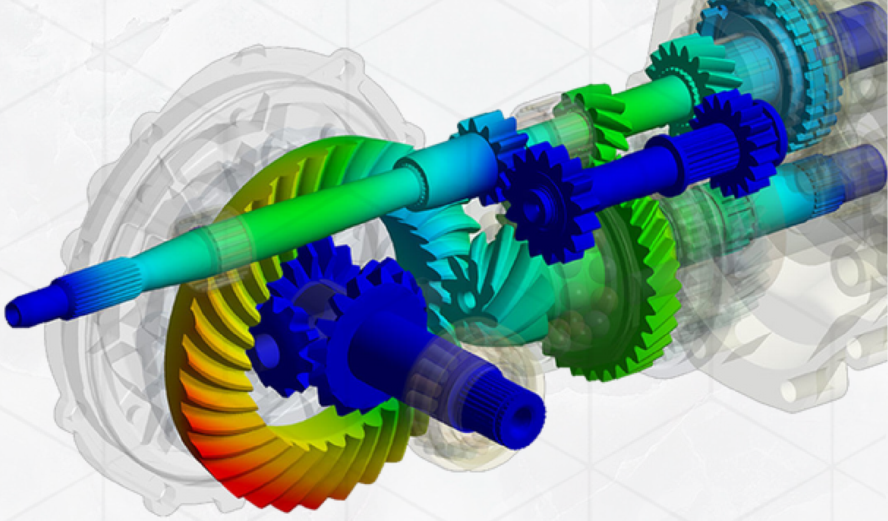

CASE STUDY

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MISSION DESIGN AND ANALYSIS TOOL DEVELOPMENT

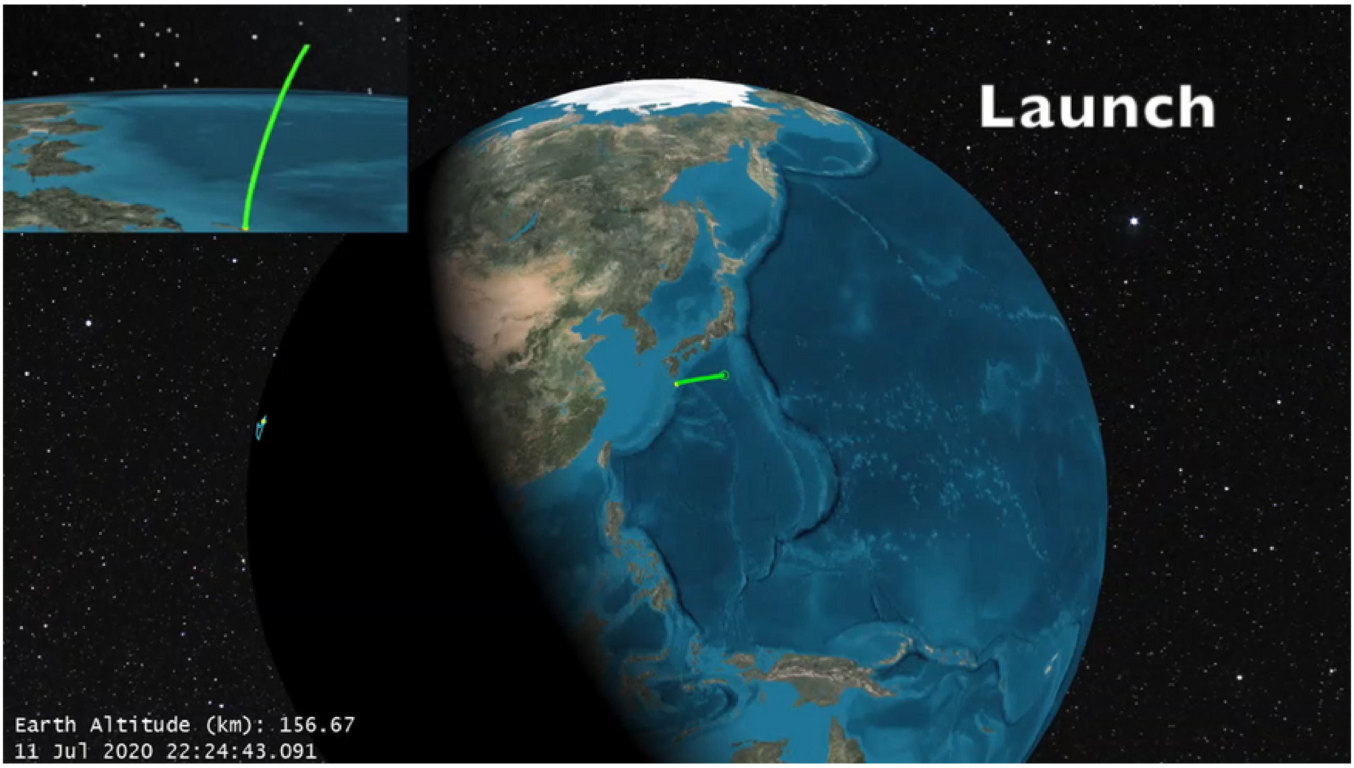
INTRODUCTION

In the ever-evolving field of space exploration, tools like Ansys Systems Tool Kit (STK) and Orbit Determination Tool Kit (ODTK) are pivotal in advancing our understanding.

Mohammed Bin Rashid Space Centre (MBRSC) used STK to delve into orbital dynamics and execute highly precise orbit propagation, critical for mission design and optimization. Beyond its applications in maneuver design, this versatile toolkit extends its utility to Near Earth to Deep Space Mission Analysis, showcasing its adaptability across diverse orbital regimes.

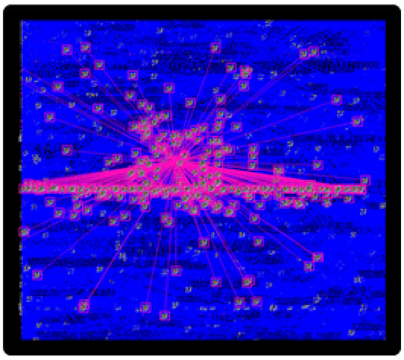
MBRSC leverages ODTK, particularly in Deep Space Missions, where GPS data is unavailable, employing methods such as one-way and two-way Doppler and Delta Differential One-way Range (Delta DOR) for precise orbit determination. ODTK also plays a pivotal role in initializing STK by feeding it different types of Station Data. In this case study, we delve into how MBRSC effectively utilized STK and ODTK in initializing and designing complex space missions and developing analysis tools.

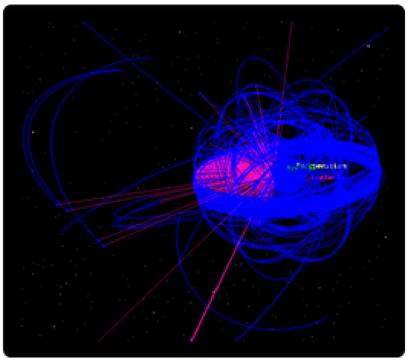
DEEP SPACE MISSION EXAMPLE - EMM 2015 DESIGN



EARTH MISSION SPACECRAFT

The Spacecraft Simulation Project represents an initiative of space mission preparedness. Spearheaded by the integration of technology, this project involves the loading of over 2000 spacecraft objects into Systems Tool Kit (STK). A component of this simulation lies in the utilization of a highly precise orbit propagator, ensuring the accuracy and realism of the spacecrafts' trajectories.





The primary objective is to meticulously calculate access between each spacecraft and a designated target, with a specific focus on communication handshakes. In the event of a handshake not being established and encrypted data reception encountering anomalies, the project's ultimate goal is to systematically narrow down potential causes. Simulating these scenarios, becomes an indispensable advantage in identifying and addressing potential challenges, fortifying mission preparedness.

ORBIT PROPAGATORS

The Orbit Propagators project spotlights an approach to orbital mechanics, featuring a robust orbit propagator designed specifically for Earth missions. This cutting-edge propagator incorporates a high-fidelity N-Plate Model, emphasizing precision and accuracy in trajectory predictions. The N-plate model approximates the shape of the satellite by a collection of flat plates, each of them having different reflectivity properties representing the different sides of the satellite. In this approach the magnitude of the SRP acceleration will vary depending on the satellite's orientation with respect to the Sun. In 2015, a significant milestone was achieved when a STK plug-in was coded to use the N-Plate Model. Furthermore, a prototype utilizing this advanced orbit propagator was subjected to rigorous testing, yielding exceptional results. The N-plate model was introduced in STK in version 11.7.

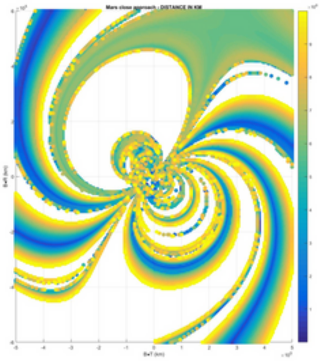
Name	User Comment	
Moon	Lunar Third Body Force	Third body e
NRLMSISE 2000	Drag with NRLMSISE 2000 Atmospheric Density Model	Drag with NR
Sun	Sun third body effect	Third body e
Radiation Pressure	Albedo and thermal radiation pressure	Albedo and t
NPlate SRP	NPlate SRP model	NPlate SRP m

```
#                   ___     Sensor Shield
#                   | |     Spherecial Payload
#                   |_|     Convert Spherecial Payload to Hex (Maybe Add Smaller Hex Areas)
#                  |_|_|    Hexagonal Body
#              ____|_|_|____ Wings 1,2,3,4
#                  /\ /\    BodyEngine
#
# [Plate Name] [Group Name] [Plate Type] [Area (m^2)]  [Unit Normal Vector (X, Y, Z)] [Spec.Reflect.] [Diff.Reflect.]
  PlusX          Body          B          2.92085        1.0   0.0   0.0       0.80      0.20
  MinusX         Body          B          2.92085       -1.0   0.0   0.0       0.80      0.20
  PlusY          Body          B          2.92085        0.0   1.0   0.0       0.80      0.20
  MinusY         Body          B          2.92085        0.0  -1.0   0.0       0.80      0.20
  PlusXMinusY    Body          B          2.92085        1.0  -1.0   0.0       0.80      0.20
  MinusXPlusY    Body          B          2.92085       -1.0   1.0   0.0       0.80      0.20
  PlusYMinusX    Body          B          2.92085        1.0  -1.0   0.0       0.80      0.20
  MinusYMinusX   Body          B          2.92085       -1.0  -1.0   0.0       0.80      0.20
  PlusZ          Payload       B          2.17766        0.0   0.0   1.0       0.00      1.00
  MinusZ         BodyEng       B          2.28113        0.0   0.0  -1.0       0.40      0.60
  Wing1PlusZ     Wings         B          1.49250        0.0   0.0   1.0       0.90      0.10
  Wing1MinusZ    Wings         B          1.49250        0.0   0.0  -1.0       0.00      1.00
  Wing2PlusZ     Wings         B          1.49250        0.0   0.0   1.0       0.90      0.10
  Wing2MinusZ    Wings         B          1.49250        0.0   0.0  -1.0       0.00      1.00
  Wing3PlusZ     Wings         B          1.49250        0.0   0.0   1.0       0.90      0.10
  Wing3MinusZ    Wings         B          1.49250        0.0   0.0  -1.0       0.00      1.00
  Wing4PlusZ     Wings         B          1.49250        0.0   0.0   1.0       0.90      0.10
  Wing4MinusZ    Wings         B          1.49250        0.0   0.0  -1.0       0.00      1.00
```

CASE STUDY

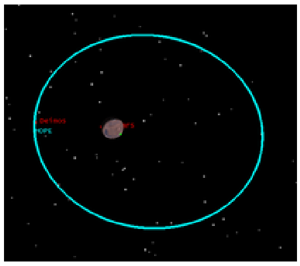
FIRST STATE SPACE

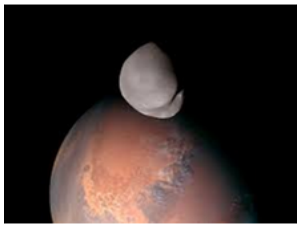
In the pursuit of ensuring planetary protection, the Mars Collision Avoidance Map Creation case introduces an innovative approach in the case of spacecraft loss of contact. Utilizing Julia to run multiple instances of Systems Tool Kit (STK), the objective was to generate a comprehensive map on the B-plane, covering a 50-year timeframe. The outcome is the creation of the first "State Space" map of a planet, with Mars as the focal point. Targeting the white areas of the B-plane, ensured that the spacecraft would have not collided with the red planet for at least 50 years, in case the burn on the B-plane did not occur for any reasons. This achievement showcases the capability to mitigate potential loss of contact and preserve planets from human contamination.



DEIMOS CAMPAIGN

The objective of this project was to capture the highest resolution images of Deimos, one of Mars' moons. The study compares the efficacy of the STK Propagator against a subsidiary software for mission planning and maneuver design. The primary goal was to strategize maneuvers that would enable the approach to Deimos within a distance of 1000 km, as per the mission requirements. The simulation results showcased the superiority of STK as a propagator, achieving a remarkable propagation error of only 5 km after 100 days of propagation. Through meticulous maneuver design, the distance of the closest flyby was effectively reduced to a mere 50 km, allowing the acquisition of images of Deimos from a closer distance, thanks to the high fidelity of STK propagation.





CONCLUSION

In summary, the case study highlights STK/ODTK's unparalleled significance in mission design and navigation for MBRSC missions. The orbit propagator's fidelity, reached a 5 km divergence after 100 days compared to other tools, underscores its precision. The integration of STK/ODTK with in-house tools contributed to creating the only Verified Deep Space Navigation System in the Region.