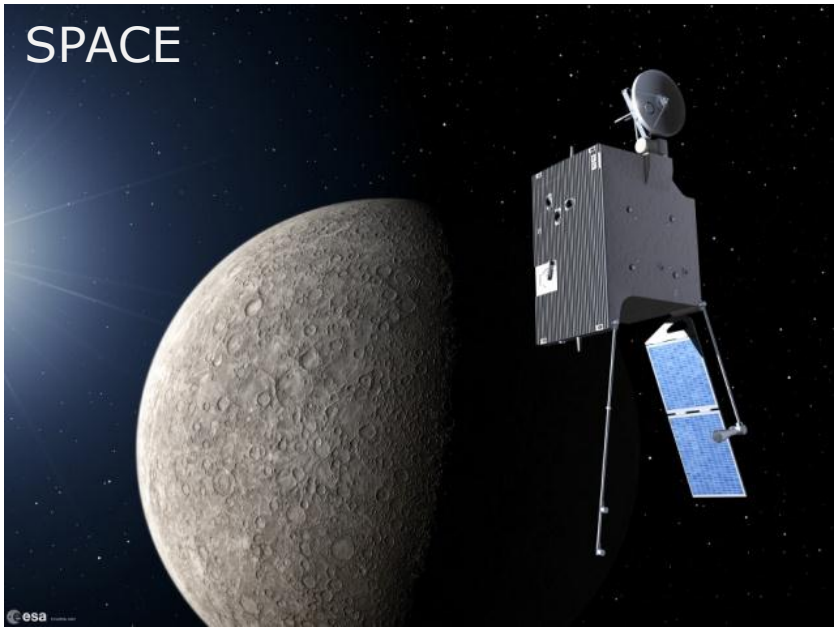


Thrust Vector Control Systems for Solid Propellant De-Orbit Motors

ESA Contract No. 4000112746/14/NL/KML

TECHNICAL DAY ON DEORBITING STRATEGIES
17 March 2015

almatech SPACE & NAVAL ENGINEERING

www.almatech.ch
info@almatech.ch

Introduction

- ALMATECH was selected for the ESA Clean Space initiative to develop and test a Thrust Control Vector (TVC) mechanism for de-orbiting purposes
- The objective of the activity is to design, manufacture and test a breadboard of a TVC mechanism
- Almatech is Prime with 2 Italian partners:

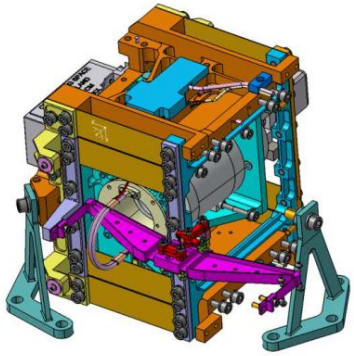
- Project status
  - 15 month program
  - Currently at requirements definition and concept selection criteria
  - TRL 4 shall be reached through the performance of the project

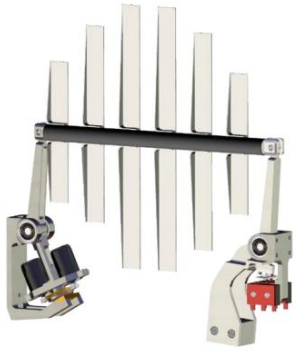
ALMATECH

Slit-Change Mechanism (SCM)
part of the SPICE instrument on board of Solar Orbiter

Corner Cube Mechanism (CCM)
part of the Infra-Red Sounder (IRS)
onboard Meteosat Third Generation (MTG)

Attenuator mechanism (ATM)
part of the STIX instrument on board of Solar Orbiter



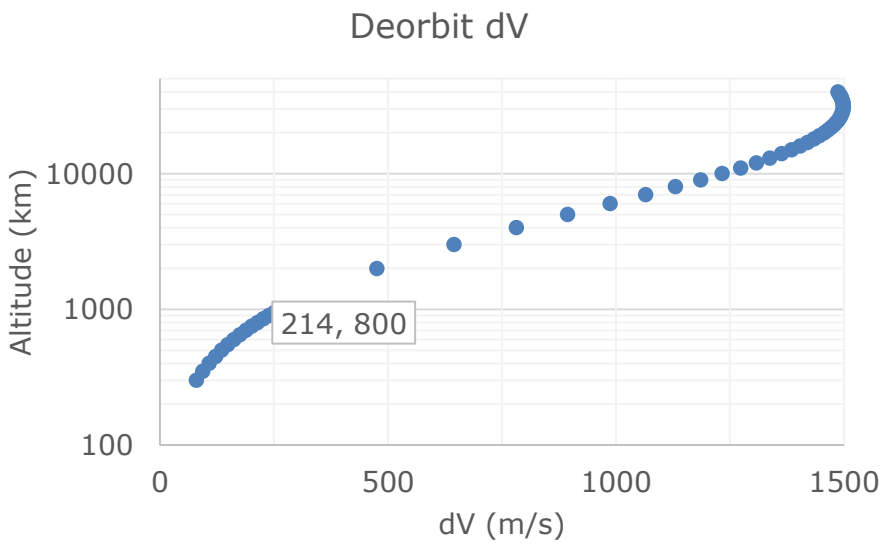


ALMATECH

- is located at the Innovation Park of the Swiss Federal Institute of Technology (EPFL) in Lausanne
- is specialized in the engineering of
  - ultra-stable structures
  - high-precision mechanisms
  - thermo-optical hardware
- core competencies:
  - design
  - analysis
  - MAIT

Reference mission

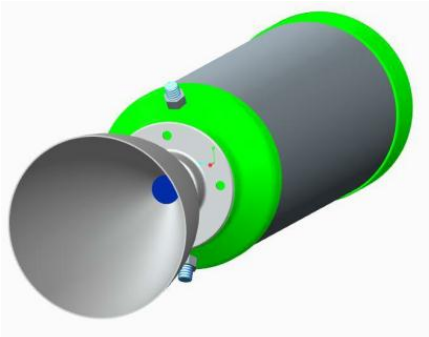
- Host spacecraft: LEO satellite
  - altitude: 800 km, sun-synchronous orbit
  - mass: approx. 1.5t
- Deorbit solid rocket motor (SRM)
  - 250 N (+/- 20%) nominal thrust level
  - cigarette burning – regression rate: 2 mm/s

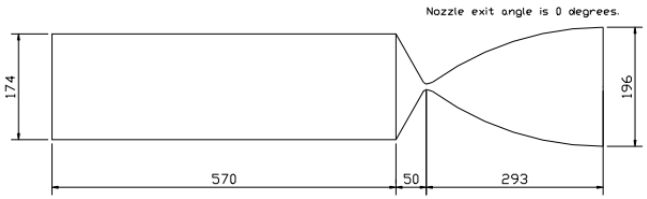


Delta-V required for deorbit

TVC system drivers

- Applicability to different spacecraft and mission types
  - Single motor and cluster configuration
  - Scaling for 3 baseline SRMs:
    - SRM Thrust level 1: 75 N +/- 20%
    - SRM Thrust level 2: 250 N +/- 20%
    - SRM Thrust level 3: 750 N +/- 20%
- Ease of integration into SRM/spacecraft – modularity, add-on system
- Reliability
- Cost effective solution – cost per unit



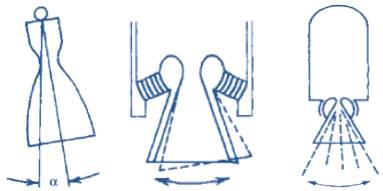


SRM baseline

Preliminary TVC technical specifications

- The TVC system shall provide pitch and yaw control. Control along the nozzle longitudinal axis is an asset.
- Performance targets
  - Thrust deflection > +/- 10 deg
  - Thrust deflection rate > 20 deg/s
- The commanded vs performed thrust vector angle shall be defined and repeatable
- Losses shall be limited at 0 degree deflection angle

Concepts – advantages and disadvantages



TVC systems

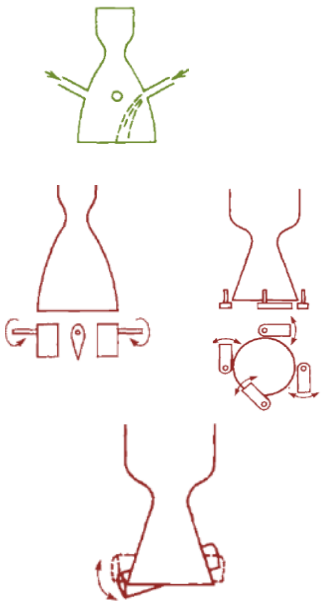
- Movable nozzle
- Movable platform
- Fixed platform, fixed nozzle

+ proven technology
+ no thrust loss
- System complexity
- Limiting modularity

- Secondary injection
  - liquid
  - gas
- Mechanical deflection
  - vanes
  - tabs
  - jetevator
  - segmented nozzle/petal/iris
  - flaps
  - axial plates
  - movable pintle, plug
- Other
  - cg shifting
  - hybrid methods

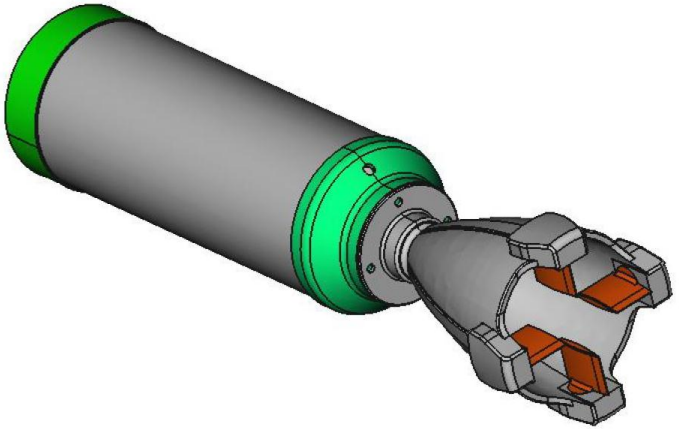
+ proven technology
+ high slew rates
- Limiting modularity
- Feed system, tank required

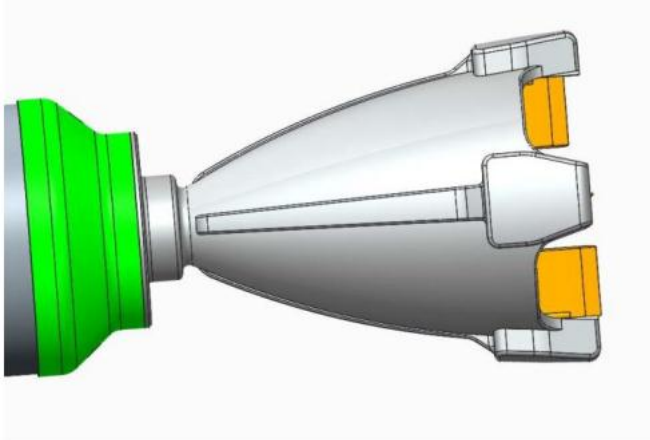
+ proven technology
+ could be designed as add-on system
- Erosion
- Thrust loss

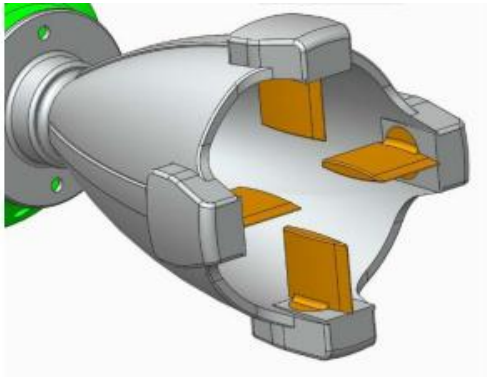


Preliminary concept iteration – Jet Vanes

- + Compact solution
- + Proven technology
- + Roll control
- - Vane erosion

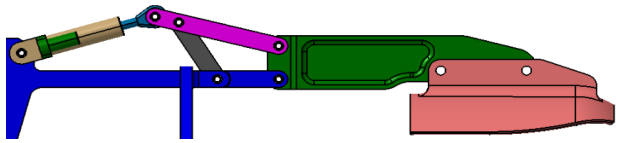


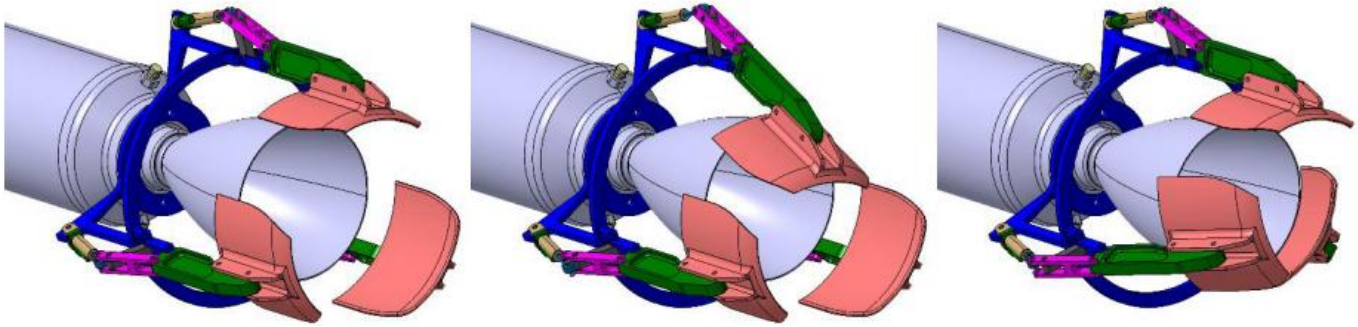




Preliminary concept iteration – Jet flaps

- + SRM-TVC thermal decoupling
- + Modularity
- - Larger volume
- - Thrust loss





Preliminary concept iteration – Moveable nozzle

- + Roll control
- + No thrust loss
- - Modularity

DeltThe thrust vector control system of the Zefiro 23 engine, part of the Vega launcher
Courtesy of ESA

Main technical challenges for the mechanism

- The mechanism should not impose operational constraints on the spacecraft and the mission
- Long burn time
- Performance prediction:
  - plume characterization,
  - simulation of plume-TVC interaction
- Performance targets
- Long in-orbit non-operational lifetime (15 years)
  - thermal loads
  - vacuum environment
  - radiation environment

Main technical challenges for the mechanism

- Some mechanisms solutions
  - compliant mechanism preferred over sliding contact systems
  - metal based flexure systems preferred over polymer based systems
  - active HDRMs systems shall be avoided for reliability optimization and cost control
  - if a lubrication system is required, solid lubrication favored over liquid lubrication
  - the complexity of the mechanism should be minimized

Thank you for your attention!

Anett Krammer
anett.krammer@almatech.ch
Aerospace Engineer

Fabrice Rottmeier
fabrice.rottmeier@almatech.ch
Head of Business Development
Senior Project Manager