Aperture Valve for the Mars Organic Molecule Analyzer (MOMA)

Charles Engler

NASA Goddard Space Flight Center

Claef Hakun, Willie Barber

NASA Goddard Space Flight Center

John Canham

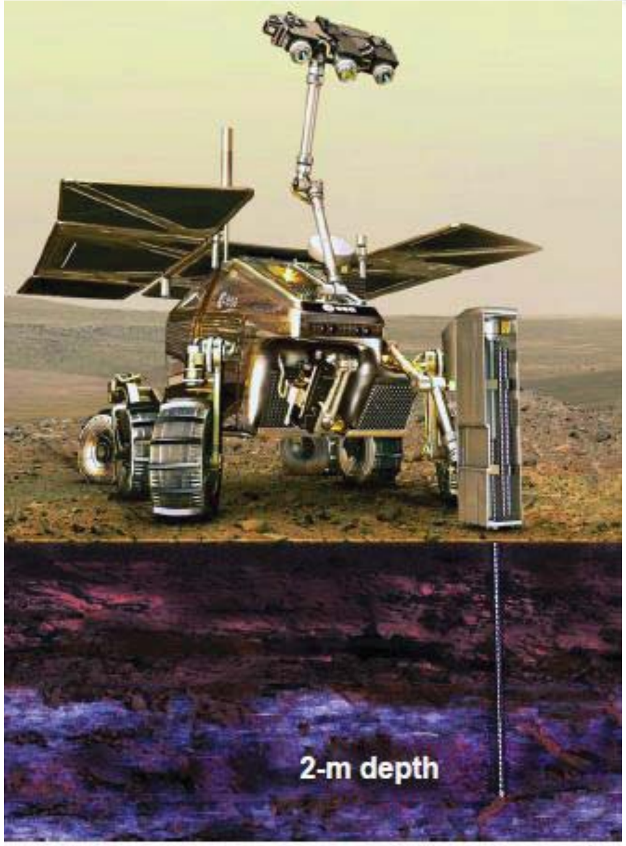
ATK Space Systems

...nd Aerospace Mechanisms Symposium

May 15, 2014

Overview: ExoMars Mission

Description	Details
Launch Date	2018
Launch Vehicle	Proton
Mission Cruise Duration	10 months
Operation Duration	180 sols (~6months)
Nominal Science	~80 sample analyses
Rover Mass	300 kg
Rover Mobility Range	Several km
Planetary Protection	Class IV
Power System	Solar Panels

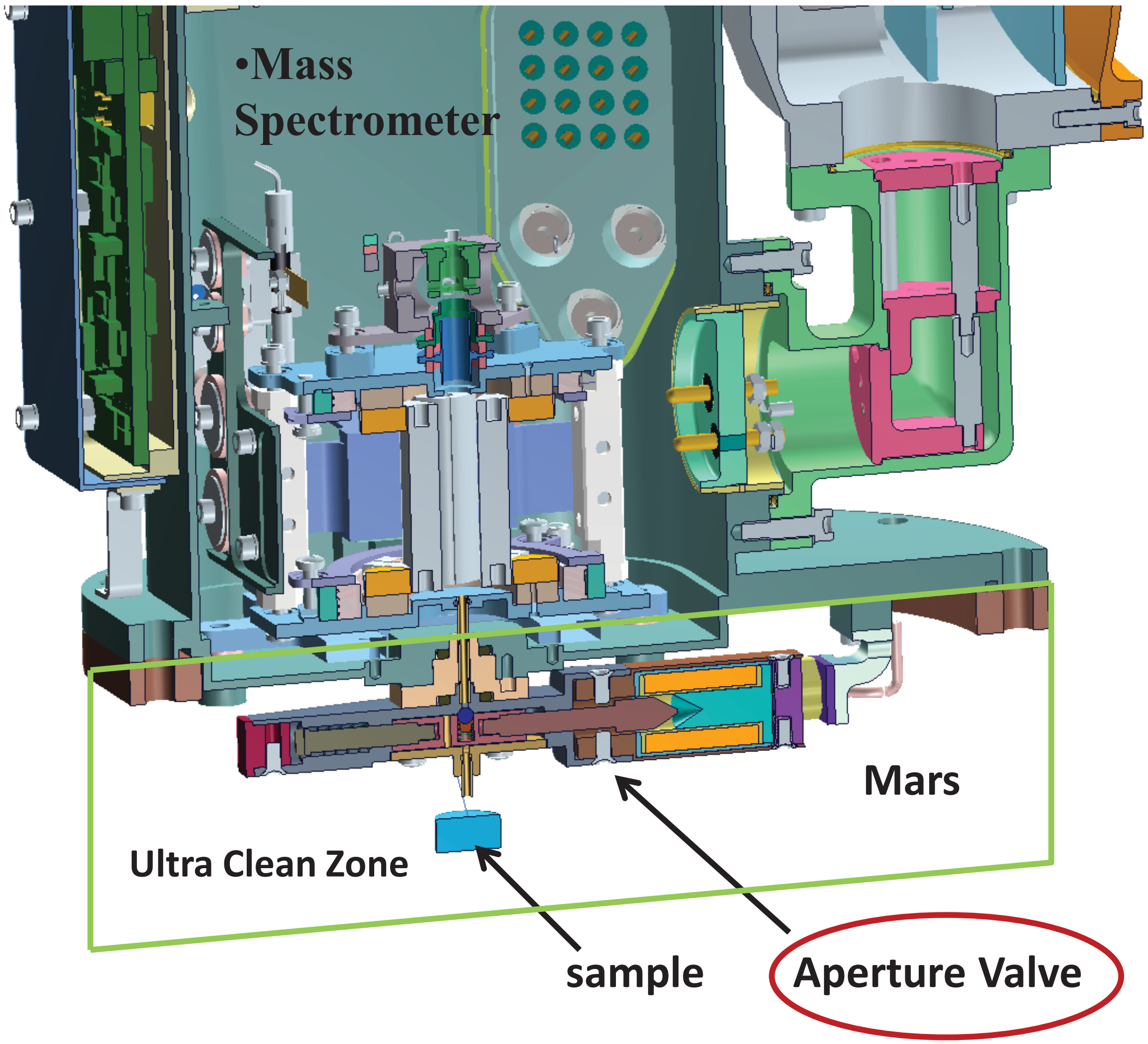


- Managed by ESA
- Instrument Payload being built by Thales Alenia Space – Italia (TAS-I)

Mars Organic Molecule Analyzer

- MOMA is a Mass Spectrometer designed to look for a wide range of organic molecules on Mars
- Led by the PI in Gottingen Germany
  – Includes partners from United States, Italy, Germany
- GSFC is delivering a portion of MOMA designated: MOMA-MS
  – Includes the Mass Spectrometer, plumbing and supporting Electronic boxes.

Overview- Aperture Valve placement within MS



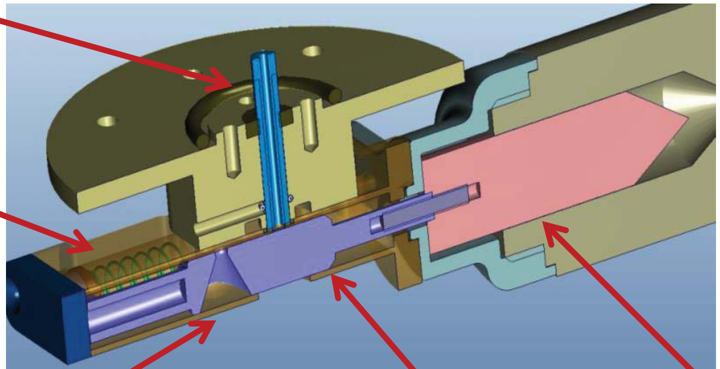
Functional purpose:

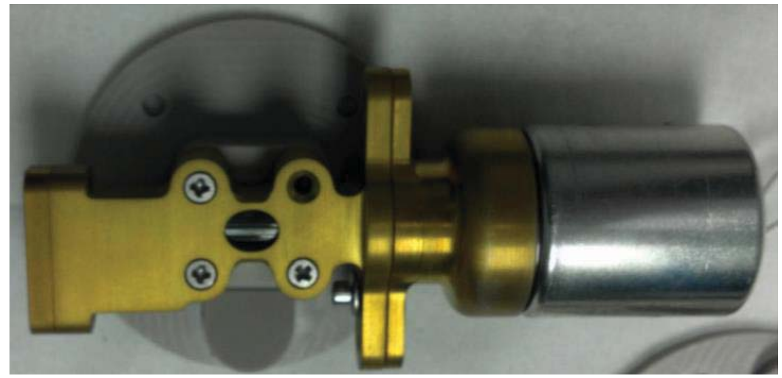
Provides a path to the ion trap that can be opened or closed on-demand.

Transfers Ions formed from laser desorption from Mars ambient (7 Torr) into the ion trap via a conductance limiting capillary (Ion Tubes)

Provides a seal to the mass spectrometer during mass measurements.

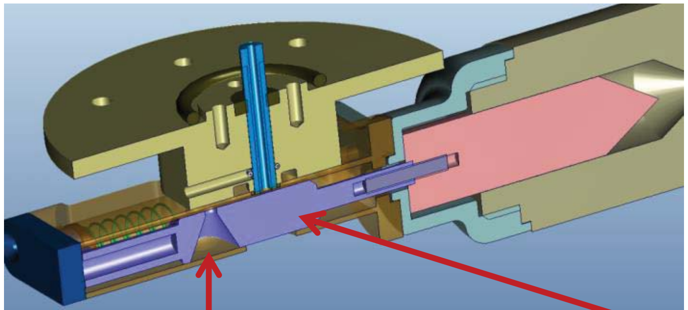
MOMA Aperture Valve

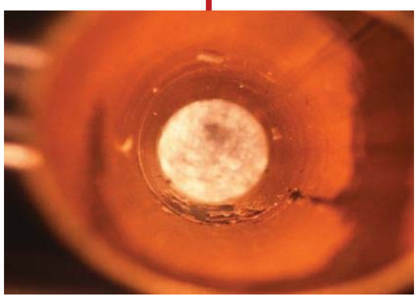




Driving Requirements	
Pressure leak rate	10E-3 cc/sec He
Operational cycle life	125,000 cycles
Operational temperature	-20°C to 50°C
Valve open/close time	<50ms
Mass	90 grams
Failure Mode	Fail closed
Power	5 watts peak
Material limitations	Non-magnetic

Issue: PVD Coatings on titanium base material





Advantages of PVD coatings

- TiN and DLC exhibit desirable combination of low coefficient of friction and high micro-hardness >80Rc - above the hardness of tool steel.
- Thin coating (.0001”) produces negligible change in part dimension.

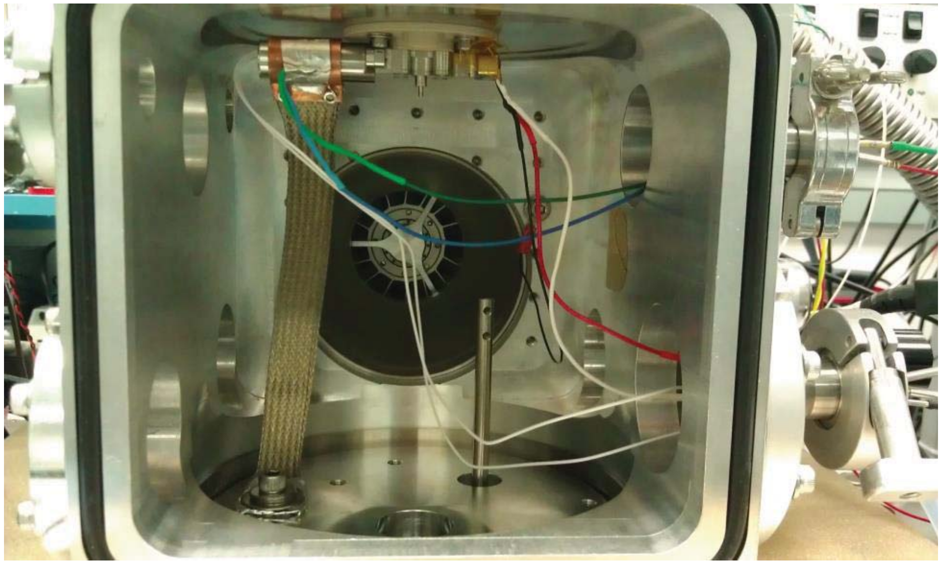
Problems discovered during early breadboard design

- Delamination of TiN coating within the bore of the valve body.
- Multi-layer PVD coatings such as TiN over DLC produced poor adhesion.

Lessons learned

- The PVD process used to apply TiN onto internal cavities and bore holes does not produce acceptable adhesion of the TiN film
- Consider having the vendor provide a witness sample prior to coating parts.

Issue: Solenoid thermal control in near vacuum



Solenoid thermal control

- Operating profile generates .27W average which must be dissipated.
- Size thermal strap for hot case then cold case to verify the valve does not become too cold.

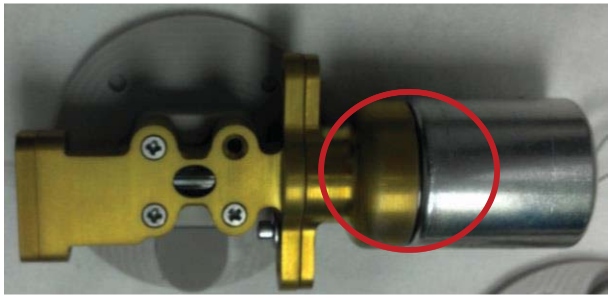
Problems discovered during initial vacuum chamber testing

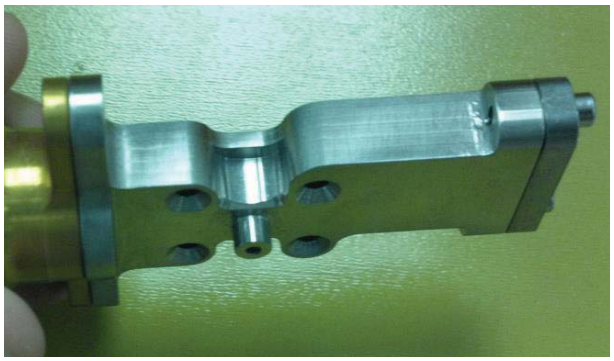
- Thermal isolation of the valve from the test chamber at 7 torr caused the solenoid to overheat.
- Non-metal solenoid parts warped from excessive heat causing solenoid failure.

Lesson learned

- Thermal strap was necessary to avoid solenoid failure.
- Thermal heat sink was incorporated into ETU and Flight valve designs.

Issue: Mechanical assembly using Small fasteners





Sine vibration test 20g, (5-100 Hz.) 2 min.

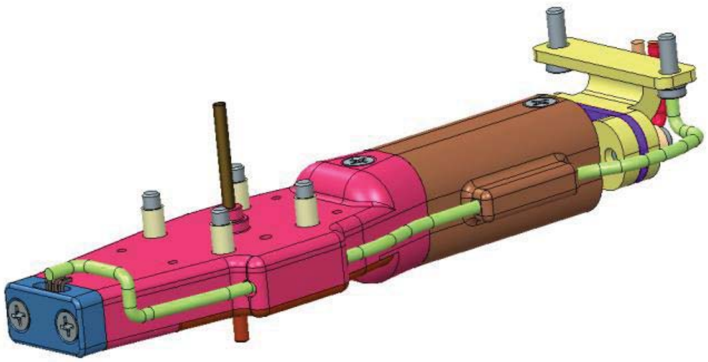
Problems discovered during vibration and life testing

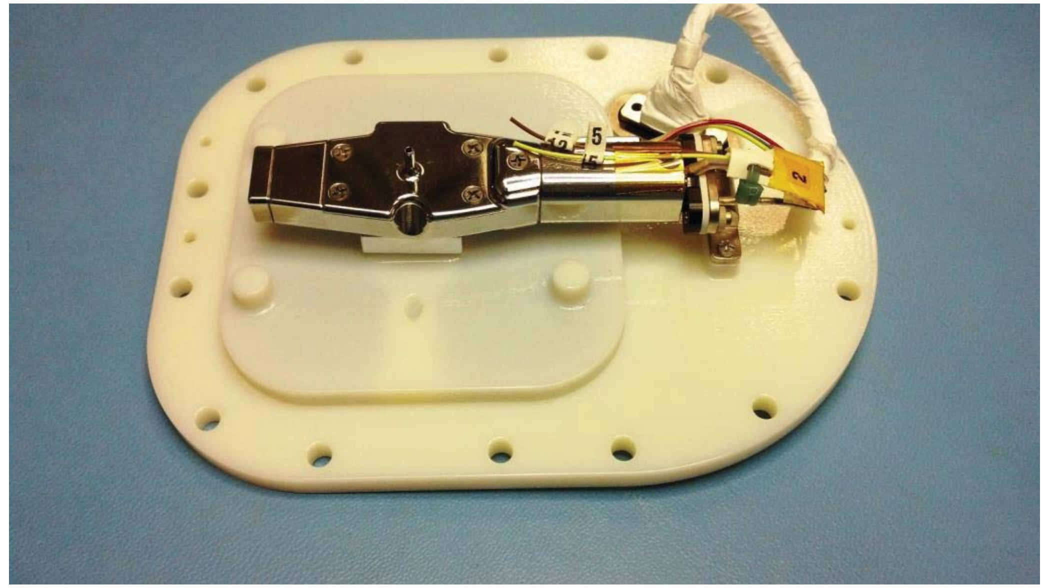
- Estimating proper preload of #1, #2 size fasteners was not exact.
- Threaded solenoid lost preload during repeated open /close cycles of the valve.

Lesson learned

- Arathane 5753 A/B applied to threads eliminated loss of fastener preload.
- Locking Helicoils were successfully used when Arathane was prohibited.

ETU /Flight Aperture valve design

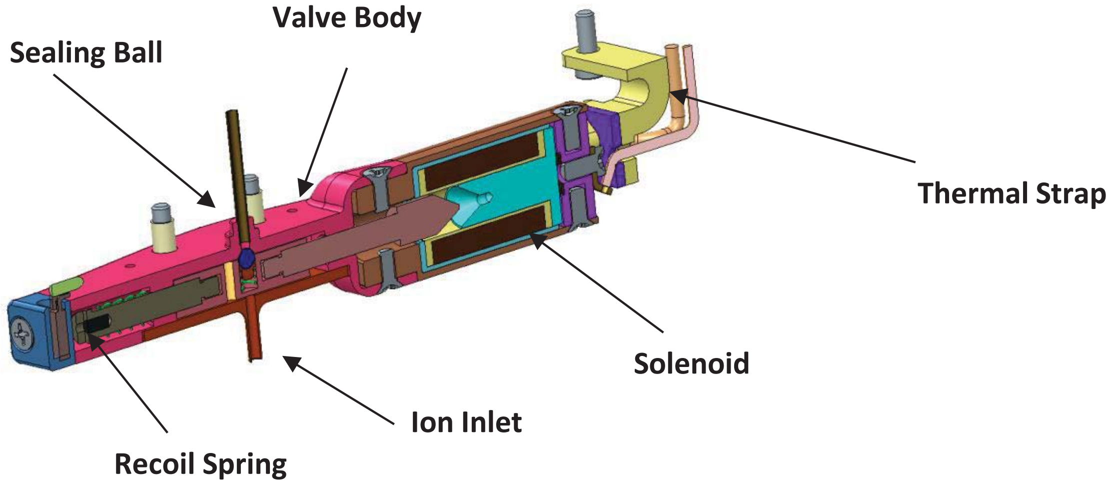




Incorporation of lessons learned

- All threaded features are secured with locking helicoils.
- PVD coatings (TiN and DLC) eliminated in favor of CRES alloy steels.
- Thermal strap was engineered into valve design.
- Plastic solenoid components eliminated in favor of metal parts.

ETU /Flight Aperture valve design



Salient features of ETU /Flight Aperture Valve

- Efficient sealing feature accomplished using check-ball type design.
- Compact footprint 96mm x 24mm x 20mm (L x W x H). @ 102g.
- Sealing capability > 1E-6 cc/sec He.
- High reliability >280,000 cycles.

Conclusions- Lessons Learned

Coatings

- The PVD process used to apply TiN onto internal cavities and bore holes does not produce acceptable adhesion of the TiN film
- Consider having the vendor provide a witness sample prior to coating parts.

Thermal control

- Thermal control was necessary to avoid solenoid failure at 7 torr atmosphere.
- Thermal heat sink was incorporated into ETU and Flight valve designs.

Mechanical fasteners

- Arathane 5753 A/B applied to threads eliminated loss of fastener preload.
- Locking Helicoils were successfully used when Arathane was prohibited.