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Stojan Madzunkov (JPL)

MARINE co-I and Electronics Lead:
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SE: Evan Neidholdt (JPL)

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Performance Model: Dragan Nikolic (JPL)

Passive Neutral Funnel Collector:
Marcin Pilinski (ASTRA Corp)

2015 IPPW
Cologne, GE

Development of JPL Flight Mass Spectrometry

1995

Linear Quadrupole Mass Spectrometer Array (QMSA)

ISS Flight TRACE GAS ANALYZER

2000

Quadrupole Ion Trap Mass Spectrometer (QIT MS)

Prior, Current or Funded Flight Instrument

Recent Work

2005

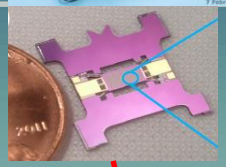
Gas Chromatography (GC)

VCAM Flight GC

VCAM Flight QIT MS

2010

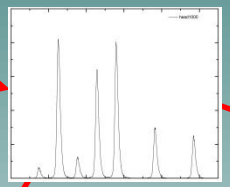
MEMS GC Development



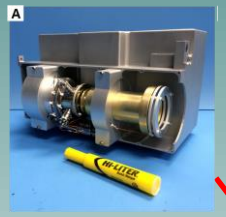
Vehicle Cabin Atmosphere Monitor (VCAM)

Wireless QIT MS

Noble Gas Isotopes 0.1% accuracy



MARINE: Europa MS

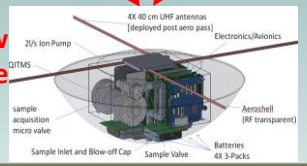


2015

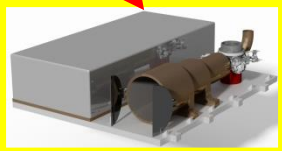
HEOMD / AES Next Generation Life Support

Spacecraft Atmosphere Monitor

Cupid's Arrow Venus Probe

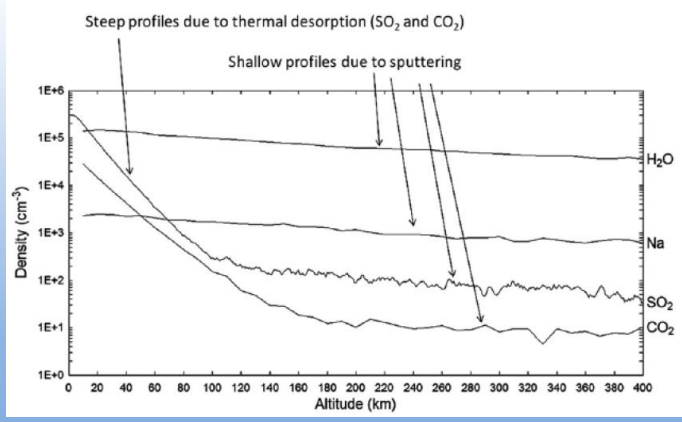


Deployment of Flyby MS on ISS



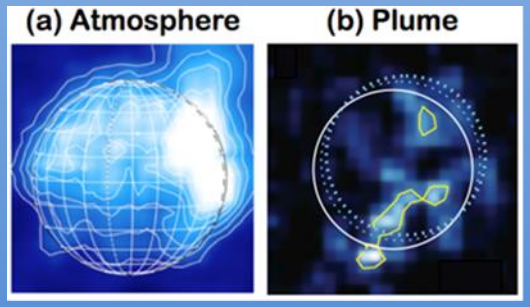
The MARINE Investigation

1. Determine the major and trace constituents in Europa's ice shell via volatiles delivered to the exosphere to assess the habitability of Europa's ocean.

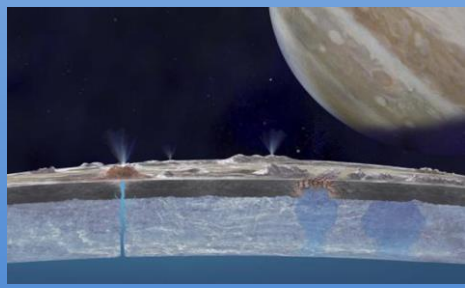


Cassidy et al. (2009)

2. Detect and characterize localized phenomena (e.g. possible plumes) and correlate detected exospheric species to geomorphic features.

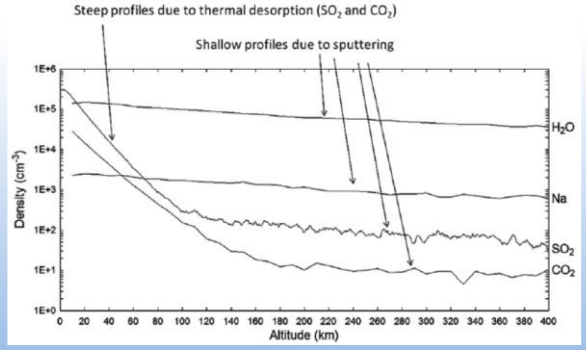


Roth et al. (2014)



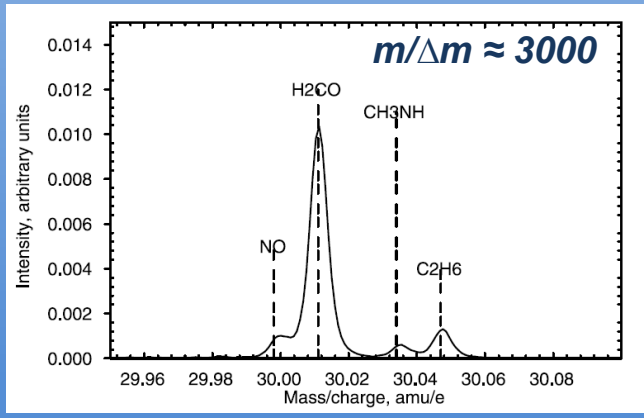
Key Challenges

1. **Low abundances require maximum sensitivity**
   - Major exospheric species densities are predicted to be as low as 10^2 cm^{-3}
   - Detection and characterization of surface-exospheric phenomenon (e.g. plumes or sputtering from light/dark regions) require highest possible real-time (per second) sensitivity.



Cassidy et al. (2009)

2. **Must have mass resolution sufficient to resolve expected target species**
   - To resolve key species (e.g. NH_3, CH_4, CH_3OH, ^{32}S and $^{16}O^{16}O$, H_2 ^{32}S and ^{34}S, H_2 ^{32}S and $^{16}O^{18}O$) requires a mass resolution $m/\Delta m$ (FWHM) ≥ 2000.



Schlappi et al. (2010)

Key Challenges

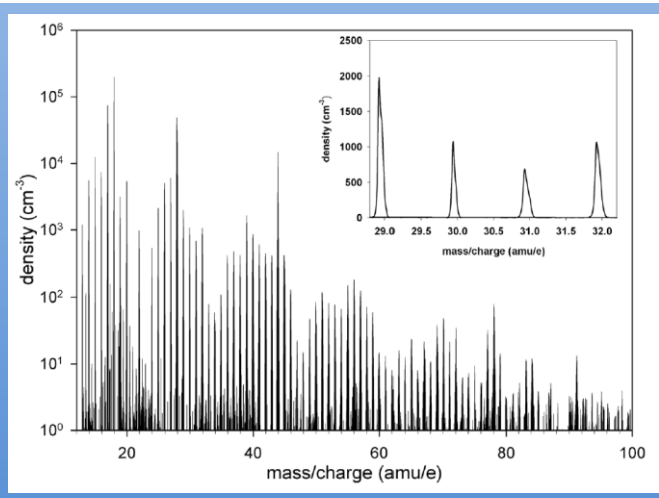
3. Achieve best possible signal-to-background ratios

S/C off-gassing and radiation induced background counts define lower bound f abundance measurements

Hydrocarbons			PAH	C-O		C-N	N-O	N-H	Fluorine
CH	C_4	C_5H_{10}	C_6H	CO	$C_2H_2O_2$	CN	NO	N	F
CH_2	C_4H	C_5H_{11}	C_6H_2	CO_2	$C_2H_3O_2$	CHN	CNO	NH	HF
CH_3	C_4H_2	C_5H_{12}	C_6H_3	HCO	$C_2H_4O_2$	CH_2N	HCNO	NH_2	CF
CH_4	C_4H_3		C_6H_4	CH_2O		CH_3N	H_6CNO	NH_3	
	C_4H_4		C_6H_5	CH_3O	C_4H_4O	CH_3NH	NO_2	N_2	Sulfur
C_2	C_4H_5		C_6H_6	CH_4O	C_4H_5O	CH_3NH_2	HNO_2		S
C_2H	C_4H_6			CH_5O	C_4H_6O	CH_3N_2H	H_4NO_2	Oxygen	N_2S
C_2H_2	C_4H_7		C_7H_3		C_4H_7O	$CH_3N_2H_2$	H_2N_2O	O	SO_2
C_2H_3	C_4H_8		C_7H_4	C_2O	C_4H_8O	$CH_3N_2H_3$		OH	
C_2H_4	C_4H_9		C_7H_5	C_2HO			$CHNO_2$	H_2O	Chlorine
C_2H_5	C_4H_{10}		C_7H_6	C_2H_2O		C_2H_2N	CH_3NO_2	DHO	^{35}Cl
C_2H_6			C_7H_7	C_2H_3O		C_2H_3N	CH_4NO_2	$H_2{}^{18}O$	^{37}Cl
	C_5		C_7H_8	C_2H_4O		C_2H_4N	C_2H_6NO	O_2	$H^{35}Cl$
C_3	C_5H			C_2H_5O			C_2N_2O		$H^{37}Cl$
C_3H	C_5H_2		C_8H_{10}			C_5H_4N	C_2HN_2O		CCl
C_3H_2	C_5H_3			C_3H_2O		C_5H_5N	$C_2H_2N_2O$		CCl_2
C_3H_3	C_5H_4		C_9H_{12}	C_3H_3O		C_5H_6N	$C_2H_3N_2O$		
C_3H_4	C_5H_5			C_3H_4O		C_5H_7N	$C_2H_5N_2O$		
C_3H_5	C_5H_6			C_3H_5O		C_5H_8N	$C_2H_6N_2O$		
C_3H_6	C_5H_7			C_3H_6O			$C_2H_7N_2O$		
C_3H_7	C_5H_8			C_3H_7O		$C_4H_4N_2$	$C_2H_8N_2O$		
C_3H_8	C_5H_9								

Approach:

- Optimize S/C ram enhancement of exospheric densities
- Minimize hypervelocity moderated effects
- Optimize transmission times for volatile species (e.g. H_2O ice, CO_2, SO_2, O_2 and clathrates of these species)
- optimize radiation shielding of detectors

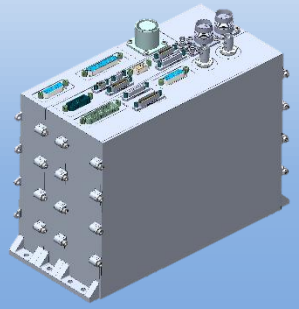


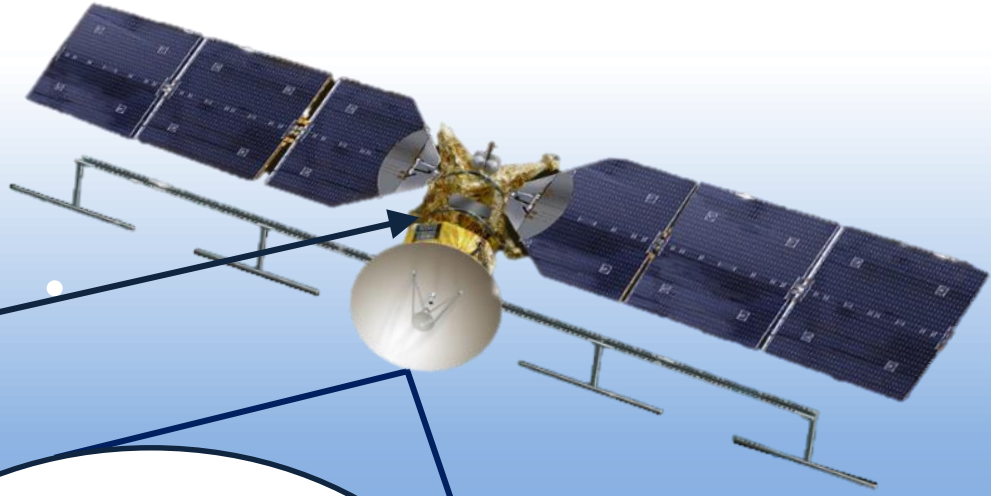
Rosetta S/C off-gassing from Schlappi et al. (2010)

MARINE Instrument

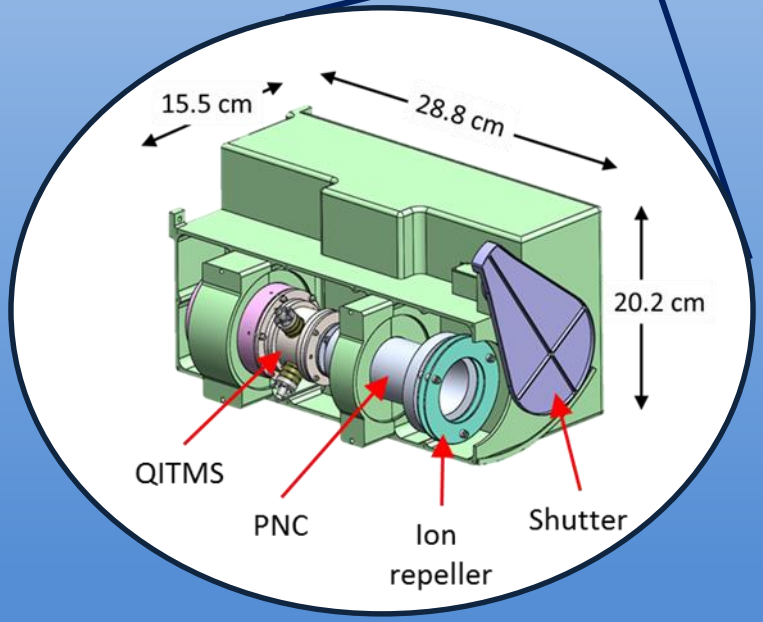
JPL

MARINE Sensor Electronics Assembly (MSEA) is mounted in the Spacecraft Electronics Vault





MARINE Sensor Head Assembly (MSHA) is mounted on the Spacecraft Neutral Mass Spectrometer (NMS) Boom

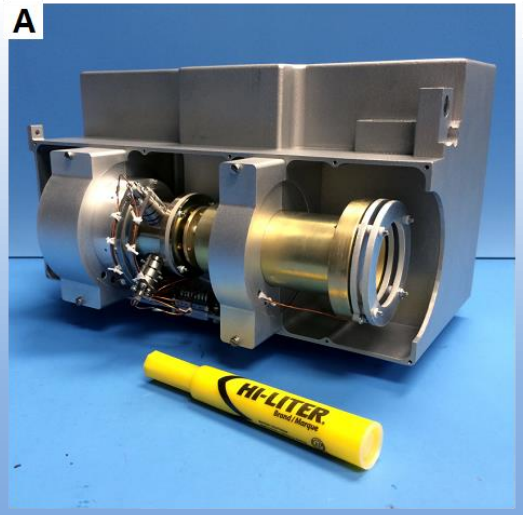


MARINE

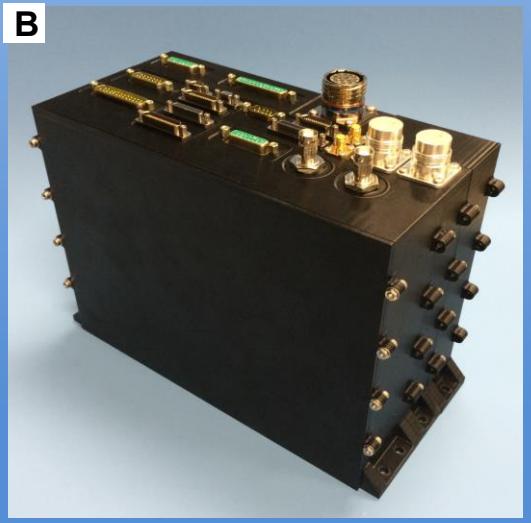
MARINE Instrument

JPL

A



B



Total Mass: 9 kg (Rad Hard)
Power: 41 W

Mass Resolution m/Δm ≈ 4000 FWHM
Mass Range: 2 - 600 Da
Greater than 1000:1 rejection of s/c offgassing

Sensitivity > 5 counts/cm^3/sec

(more than 100x greater sensitivity than any other MS)

Engineering model developed under 2013 ICEE Award

Will complete environmental (thermal/vac, vibe) in FY15

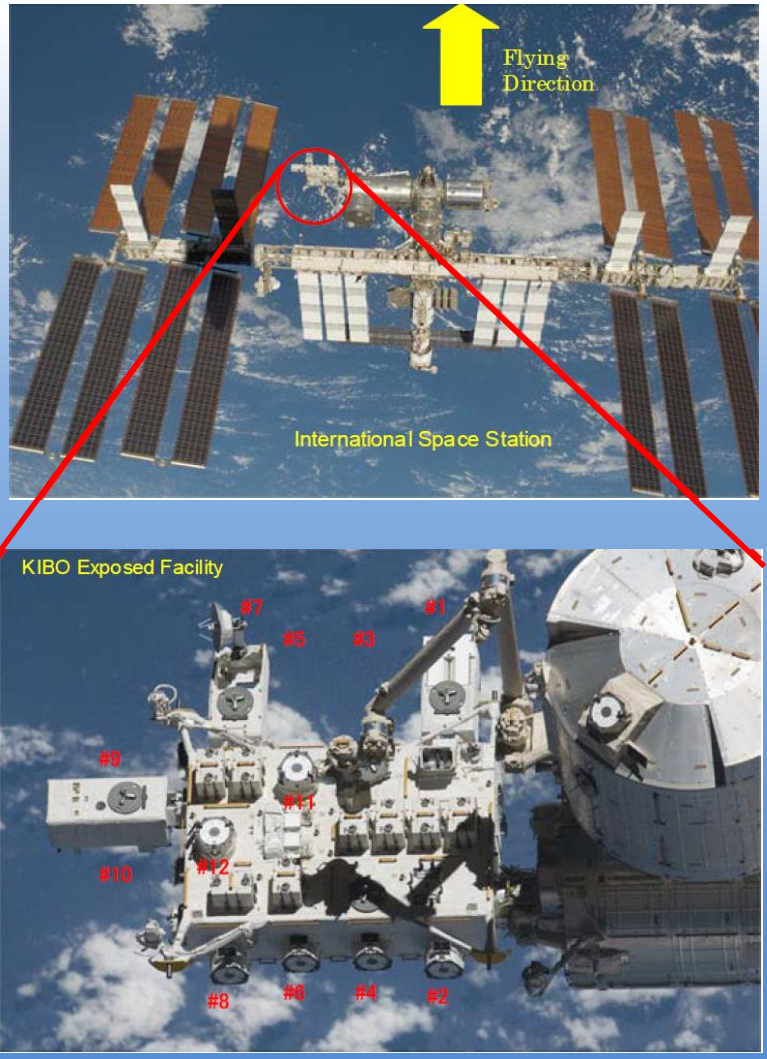
Zero TEMCO Major Weakness from Europa Clipper Review

Unfortunately Not Selected for Europa Clipper

MARINE

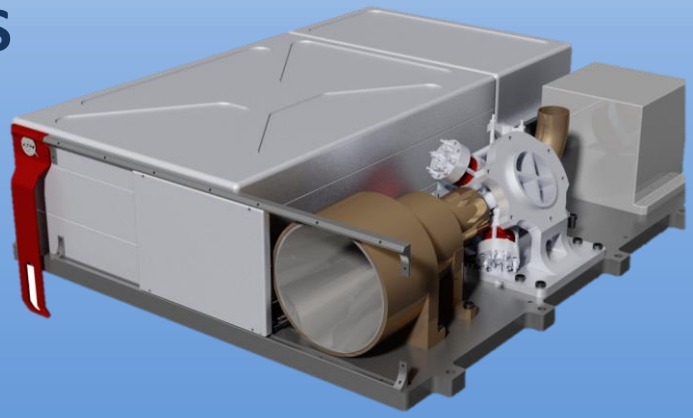
~~Europa~~

New! Low Cost 2017 Demonstration of MARINE



Low Cost Approach

Take engineering model and do minimum work required to interface to ISS

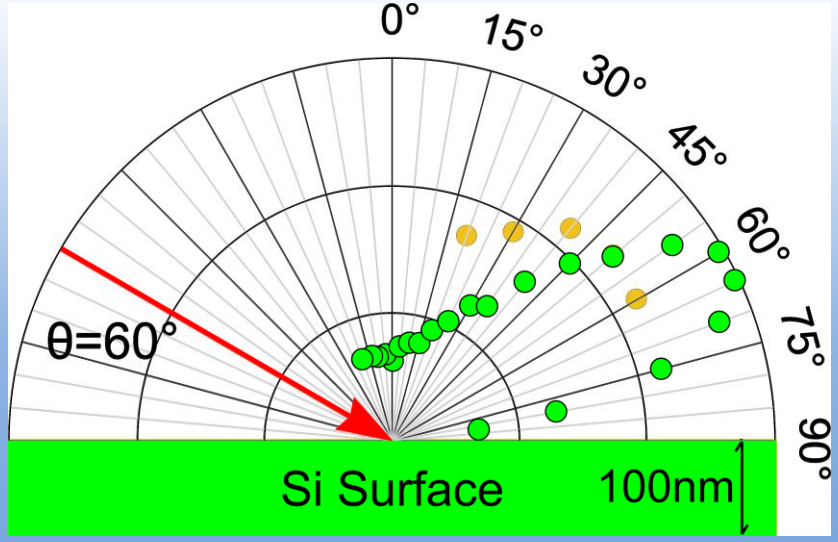


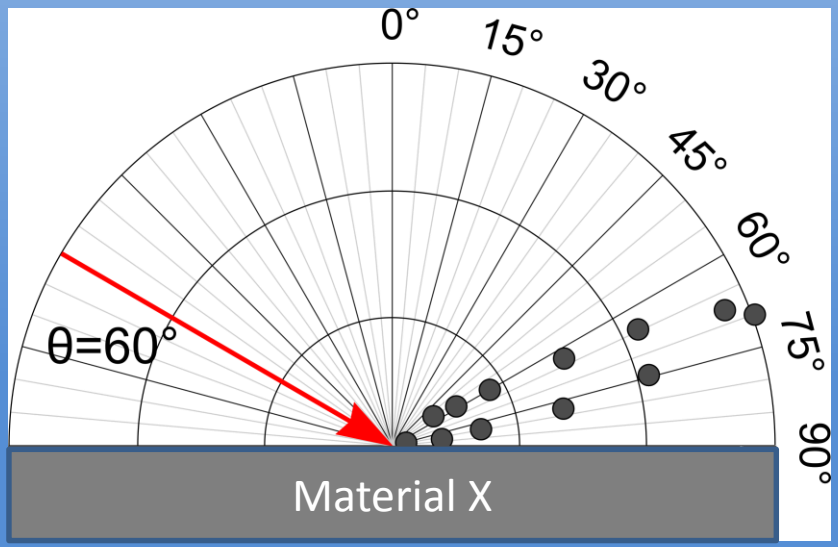
Engage NASA HTIDES and PSTARs programs to augment existing launch/deployment funding for operations and analysis.

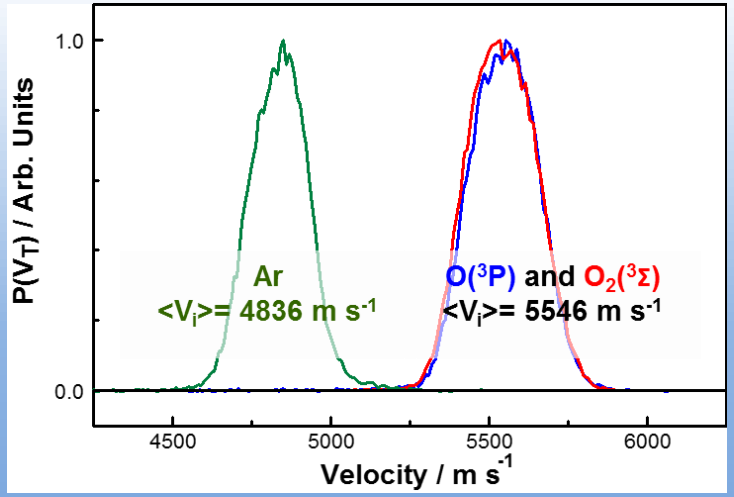
MARINE

Hypervelocity Testing

Problem: Flyby MS have velocity-induced chemistry!

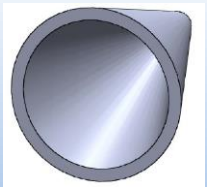




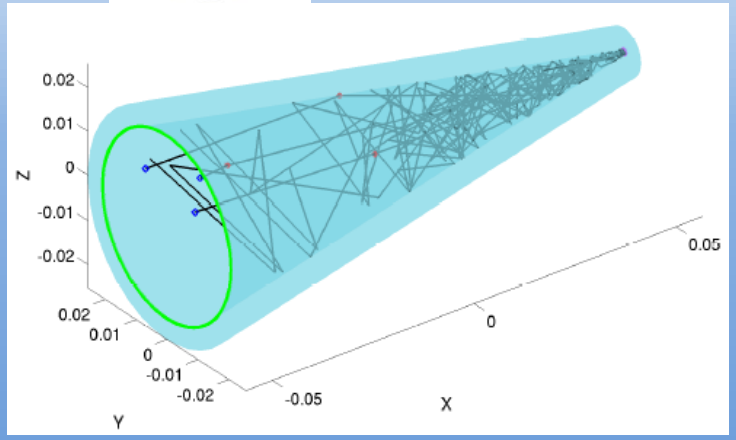


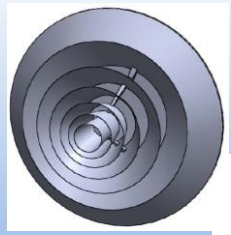
- Unique facility where collaboration will enable optimal funnel design through testing in relevant environment.
- May be possible to achieve TRL 6 through relevant hypervelocity tests.
- Funnel materials tested: Evaporated Gold, Silicon, and xxx surfaces
- Incident beam: Atomic O, O2, Ar
- Next beam species: CH4, CH3OH

Ram Enhancement of Species Density

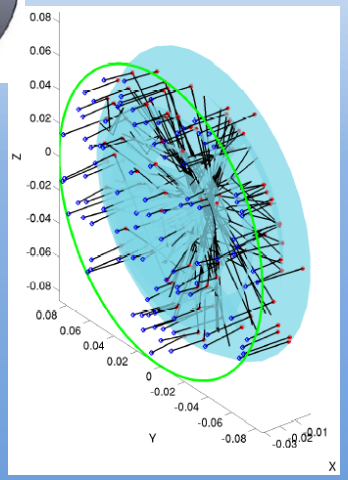


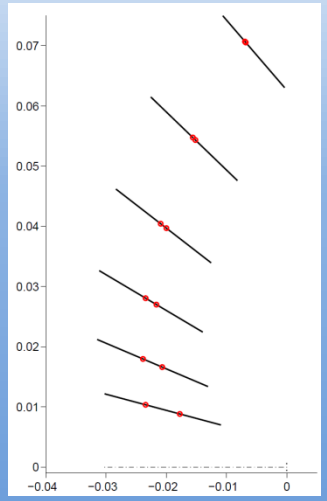
MARINE
"Simple Cone"





6 Annular Ring





Material X = Non-reactive and Super Specular Collection

Pushes Sensitivity of MARINE greater than 1000x other MS types

Summary

The MARINE instrument, developed for the Europa mission, is the most sensitive high-resolution mass spectrometer for flyby investigations of planetary targets

- Sensitivity exceeds 0.1 molecule/cm^3/sec
- Non-reactive inlet system that minimizes chemical reactions and optimizes rejection of s/c offgassing bckgrnd.

Although not selected for the Europa mission, JPL is proceeding with a flight aboard ISS in 2017.

MARINE is ideally suited for flyby and rendezvous missions to other planetary targets.