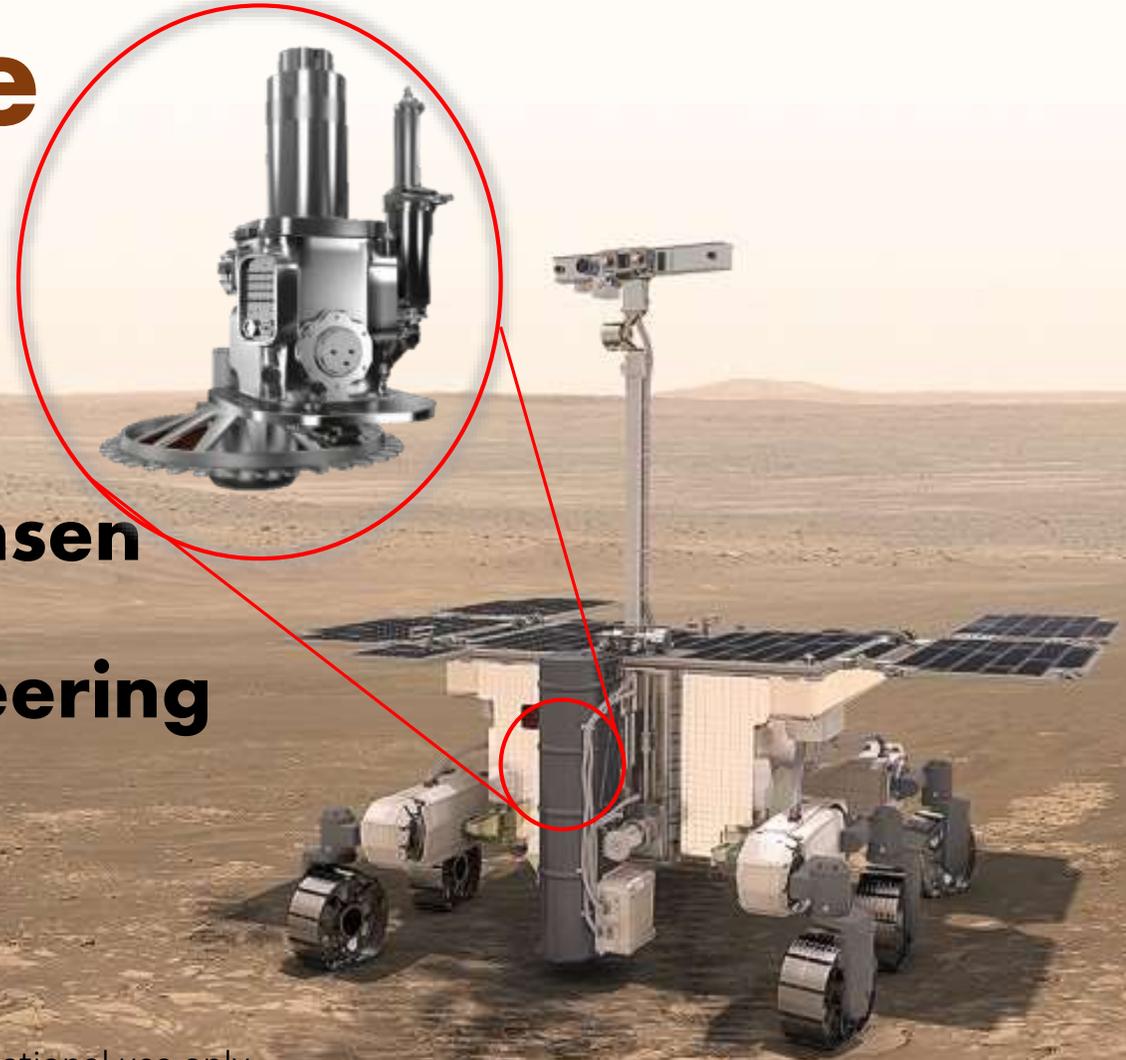


# Systems Engineering Challenges on the Mars Organic Molecule Analyzer

**Brian Ottens & Zach GonnSEN**

**NASA GSFC Systems Engineering  
Seminar**

**Aug 8, 2017**



# SYSTEMS ENGINEERING CAN BE A SUSTAINABLE & FULFILLING JOB



The ability to perform the job today such that it doesn't adversely affect future performance.

Meeting or exceeding one's expectations in success, enjoyment, and overall goal alignment.

## WE WANT TO HELP MAKE THAT POSSIBLE

# **Part 1 – The Mission**

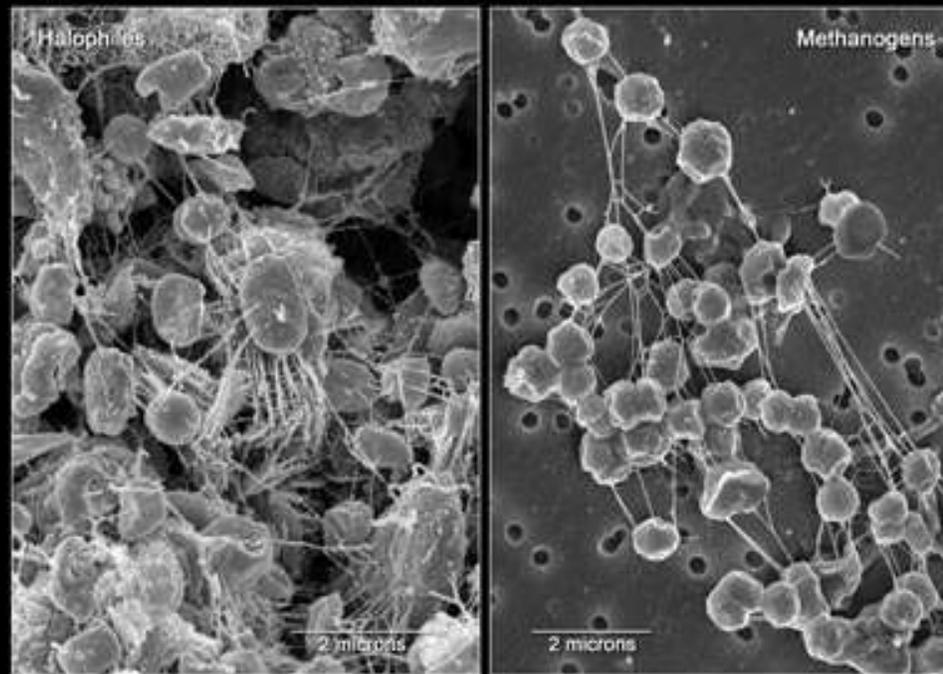
# Life is Pervasive (on Earth)



In most solid-surface locations, you'd have to take extraordinary measures to avoid encountering life



A vent in the NE Pacific. A bed of tube worms cover the base of the black smoker.



Microbes that Survive in Extreme Conditions  
Maryland Astrobiology Consortium, NASA, and STScI • STScI-PRC06-48

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THE SCIENCES

## Newly Discovered Microscopic Worm Thrives in Gold Mines a Kilometer Underground

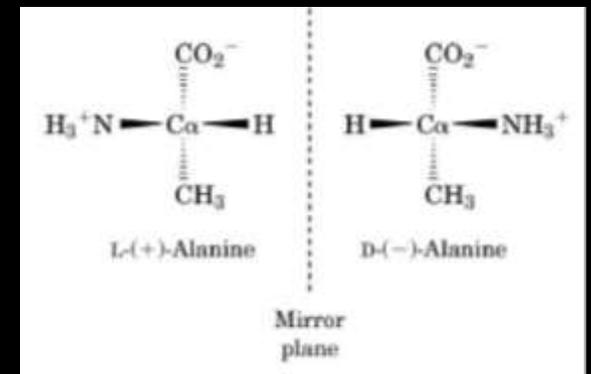
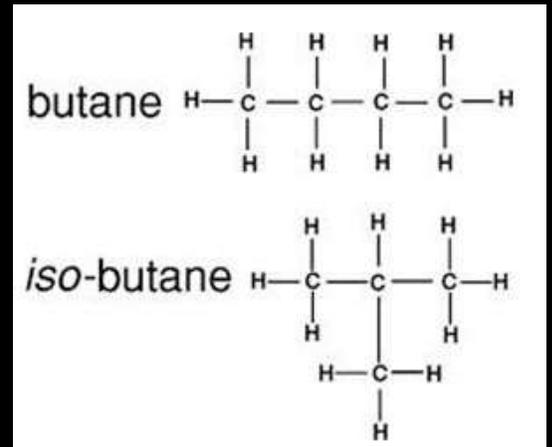
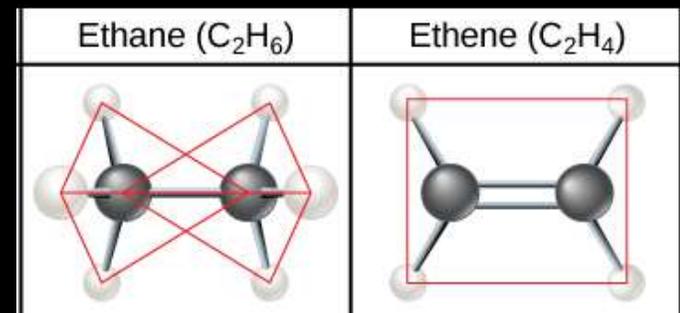
High temperature, low oxygen and permanent darkness are no problem for a previously unknown species of nematode

# Carbon

- Why is it special?
  - A single Carbon molecule can form 4 covalent bonds.
  - Can create several types of isomers
  - Can form long chains of molecules together.
  - Can form single, double, and triple bonds.

These options combine to make an exceptionally high number of potential molecules, and as expected it is very active.

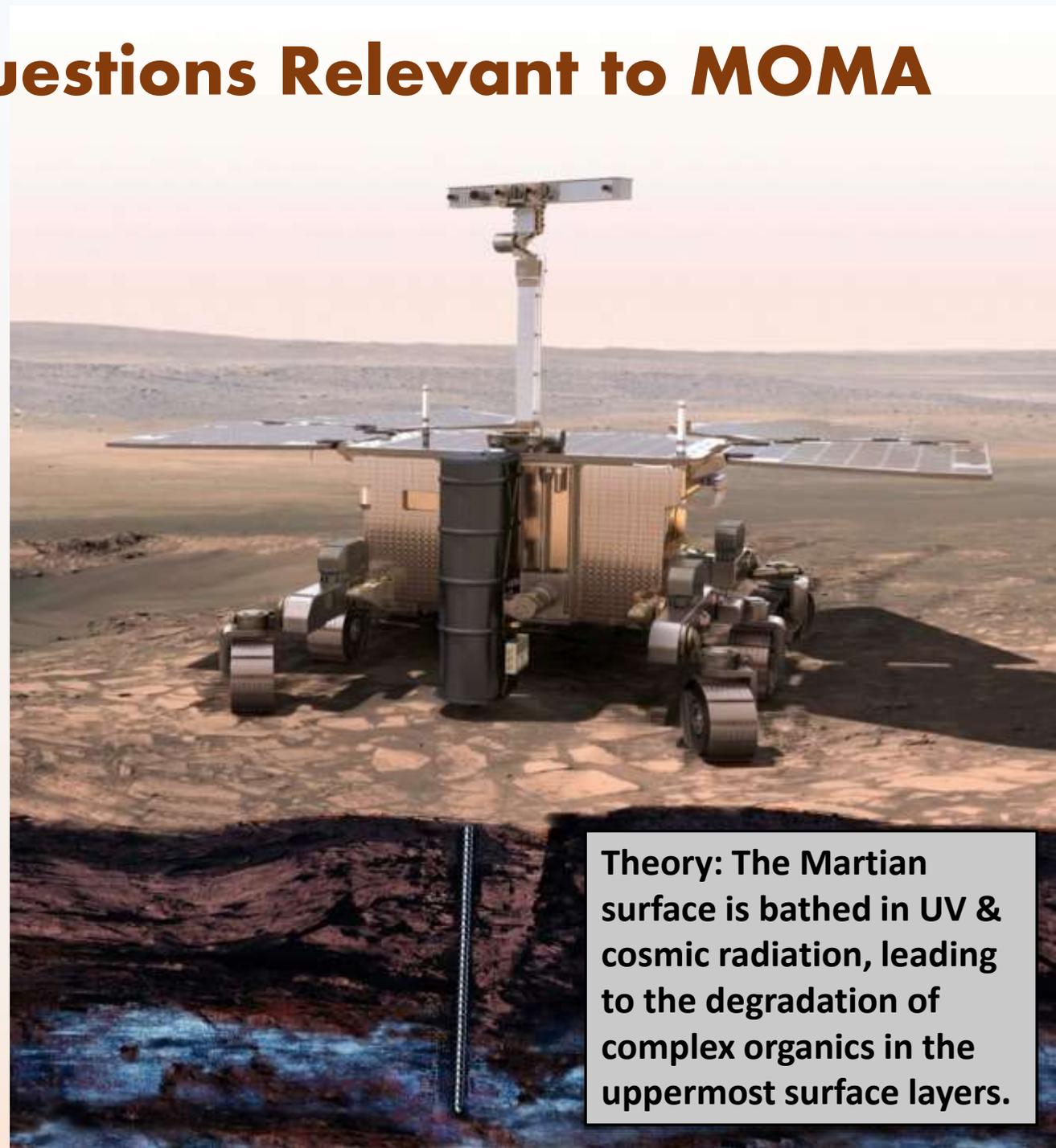
- On Mars:
  - Tons of Carbon present, one only has to look as far as the atmosphere (96% CO<sub>2</sub>)
  - Rare discoveries of non-atmospheric Carbon at the surface (e.g. Freissinet et al 2015)
  - No sign of complex or interesting compounds that would hint at the availability of necessary biocompounds



## 2 Key ExoMars Science Questions Relevant to MOMA

**Does the Martian subsurface hold a rich and active chemical environment ?**

**Are there signs of life on Mars, extinct or extant?**



**Theory: The Martian surface is bathed in UV & cosmic radiation, leading to the degradation of complex organics in the uppermost surface layers.**

**Video**

# SEARCHING FOR LIFE ON THE RED PLANET | **EXOMARS**

Mission duration:

**218** Martian days

## Autonomous navigation system

Stereo cameras at the top of the 2m mast map the fastest & safest route.

Carrying:

**9** experiments

Mass:  
**300 kg**

\*Width:  
**2.5 m**

\*Length:  
**2.5 m**

\*Height:  
**2 m**

\* Dimensions with solar panels deployed

Distance to be travelled on Mars:

**4** km

## 50 motors

Power the drill, mast, cameras, solar panels and wheels.

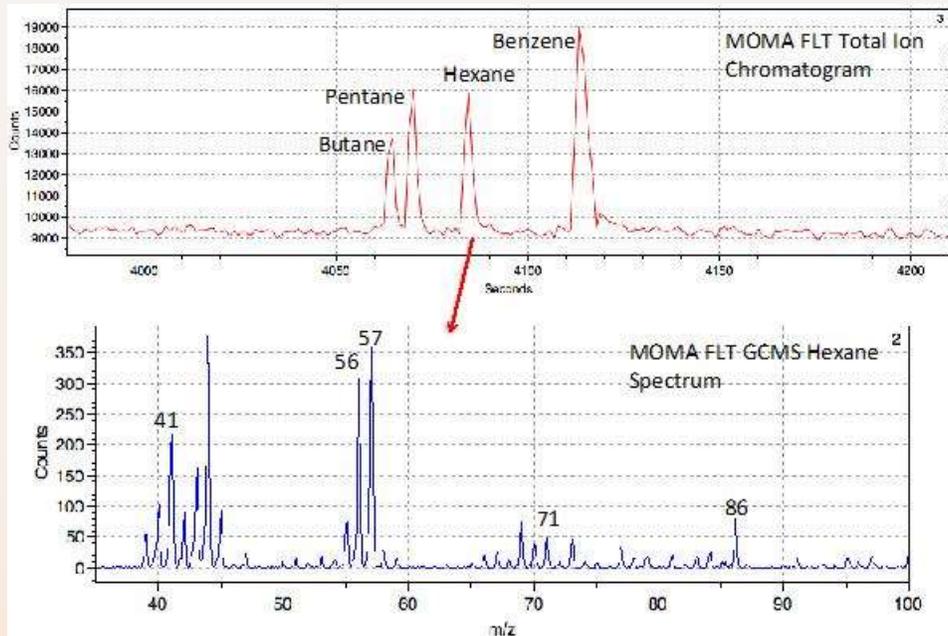
## Airbus Defence and Space contribution

Airbus Defence and Space in the UK is taking the lead in developing the rover. The rover's primary task will be to search for evidence of life, past or present, beneath the surface of the Red Planet.

# Broad Molecular Analysis via 2 Modes

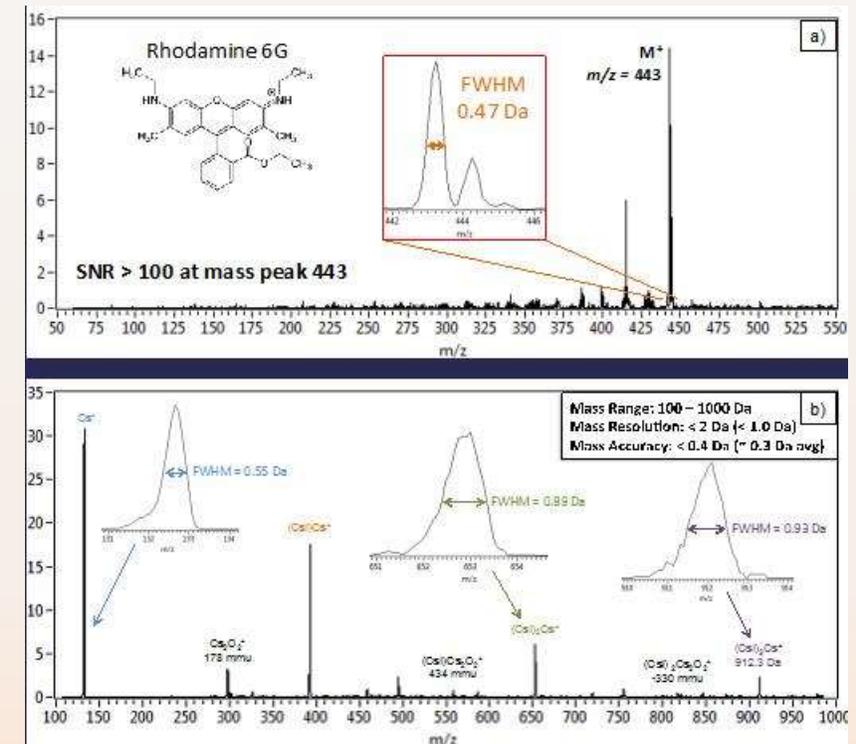
## Gas Chromatography Mass Spectrometry [GCMS]

- Separation and detection of organic classes using gas chromatography (red)
- Fingerprint MS identification of volatile compounds such as hexane (blue)
- Derivatization GCMS for less volatile species (amino, carboxylic acids)



## Laser Desorption Mass Spectrometry [LDMS]

- Laser desorption/ionization of large, nonvolatile molecules (e.g. aromatics)
- MS/MS: fingerprint structural analysis
- Detect organics even with perchlorates



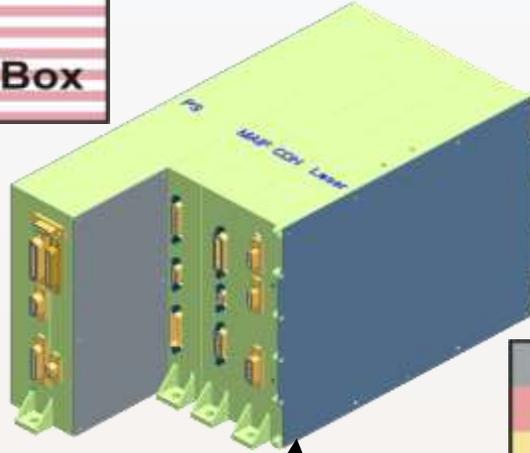
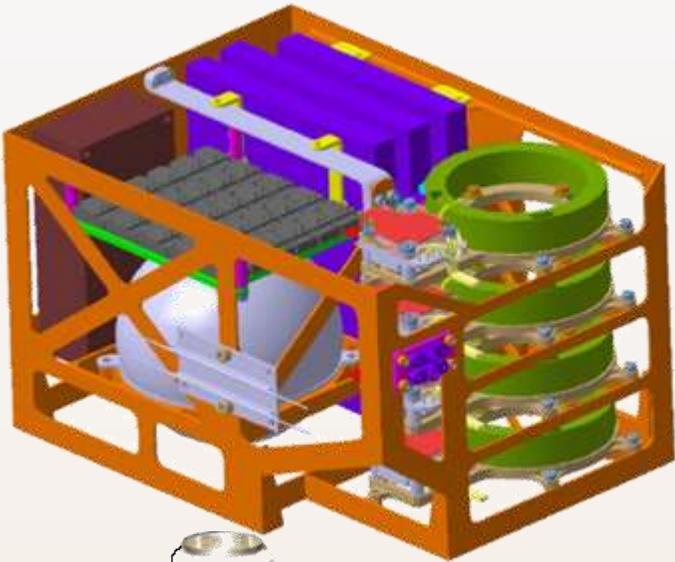
# MOMA Decomposition

**A05**  
Gas Chromatograph

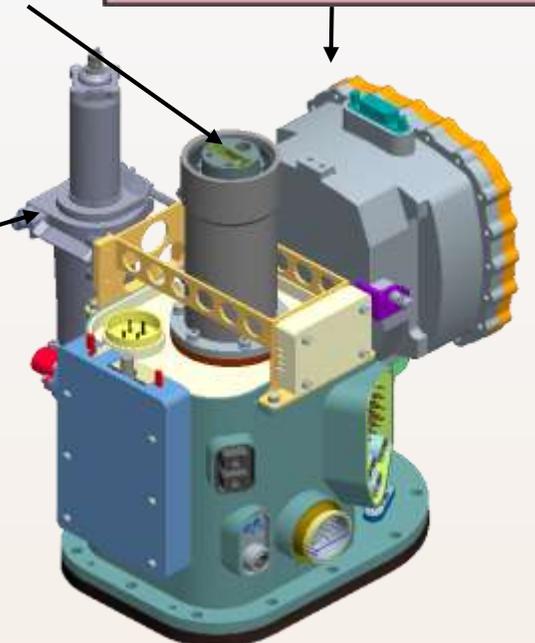
**A03**  
Main Electronic Box

**A11**  
Vacuum Pump

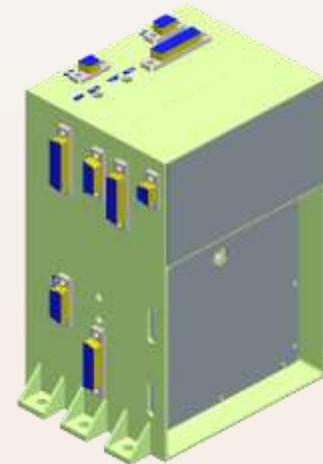
**A10**  
RF Electronics



**A06**  
Laser Head



**A07**  
Laser Pump Unit



**A04**  
Mass Spectrometer



**A09**  
Oven

**A08**  
Tapping Station

**A12**  
Secondary Electronic  
Box

# Part 2 – Two Challenges We Faced as Systems Engineers and How We Responded

 2a) Defining what a Systems Engineer does and what they're responsible for.

2b) Working with others in different cultures, norms, customs, and expectations.

“To my successor Systems Engineer, I leave a legacy of expectations and norms that you will never completely discover.”

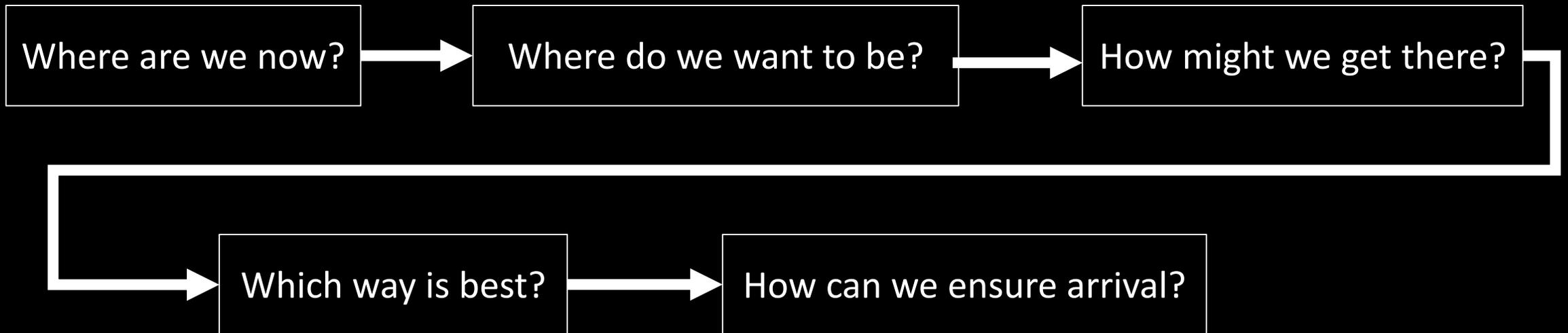
# But the good news

**You're a Systems Engineer, with skills in defining and managing team expectations. DO THE SAME THING FOR YOURSELF !**

# Planning

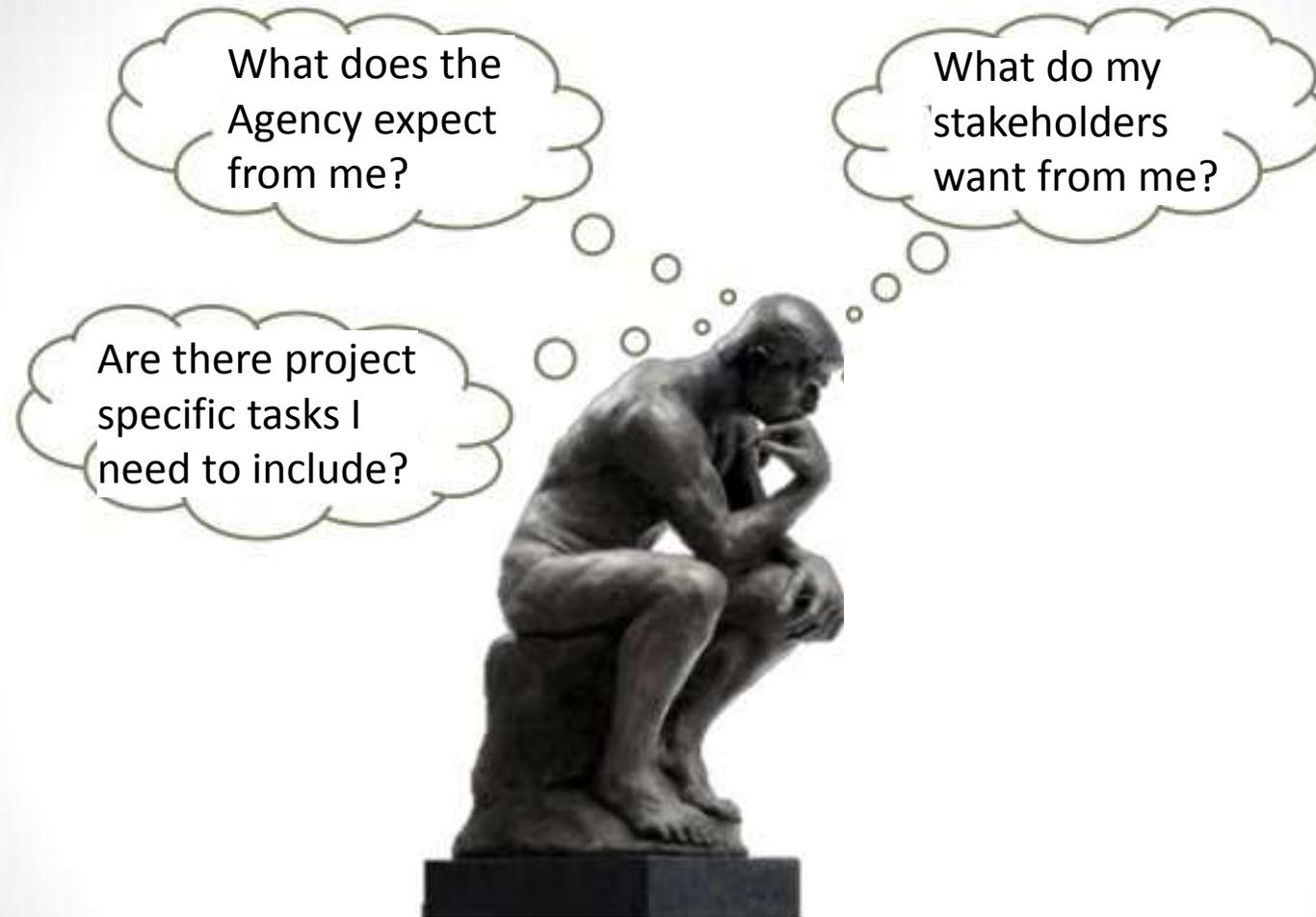
Deciding what needs to happen in the future and generating plans for action (deciding in advance).

## The Planning Process



ID#	MOMA Task Description	Estimated Time Burden	Phasing (Q2-4 of '16 or Q1 of '17)	POC1	POC2	POC3	POC4	Notes
1	Compile trending list and coordinate review of trending data. Trending analyst for 0 data point	Low	All	Zach				Adding AGC slew and change characterizations to CPT
2	POC for system level anomalies in MOMA-MS level I&T including test failures, Exp-ICD revisions, trending anomalies, etc.	High	All	Zach	Tony	Brian		See Prob/Anomaly spreadsheet
3	Participate in compiling MOMA-MS inputs and coordinate implementation for post-delivery (European) I&T	Low	All	Zach				Led by Rich H. SE participation and assistance.
4	Field ~2 per mo & simple MOMA-MS level concerns from discipline engineers, technicians, etc (estimate based on Brian's prior experience).	Low	All	Zach	Brian			
5	Management Overhead	Med	All	Brian				Systems engineering MMR, MSR & Tag-up presence, WBS budget and task management, MSR inputs (risk, tech issues & summary chart, RFA tracking, tech resources)
6	Support simple I&T flow re-plans, test descopes, emergency change of planning, etc at rate of approx ~2 per mo (estimate based on Brian's prior experience)	Low	All	Brian	Zach	Tony		
7	SE rep for environmental test planning, TRRs, break-of-config reviews, and script control board.	Low	All	Brian	Zach			SE doesn't chair. I&T will chair
8	Monthly risk updates	Med	All	Brian				
9	Make any necessary tweaks to requirements, SEMP, and other Systems Engineering Docs.	Low	All	Brian				
10	Lead generation of the MOMA-MS verification matrix and lead its population	Med	All	Tony				
11	Oversee MOMA-MS integration, test, qualification, alignment, etc by stopping by the lab every so often and see how things are going (for ETU). Participate and get directly involved with flight.	Med	All	Brian	Zach			
12	CCR, SCoRE, WOA, and Waiver Approval.	Med	All	Brian	Tony	Zach		Includes WOA data reviews, as necessary
13	PSR Preps	Med	Q1	Brian	Zach			<u>Requires management and PDLs to need very little leadership to make cohesive package. SE handles the verification section and a few open PRs only.</u>
14	Help with the ops plan to include commissioning	Low	Q1	Zach		Brian		Only minor involvement by SE (a few section assignments)
15	GOLD Rules Audit for PSR	Low	Q1	Brian				
16	2018 TVAC ("main TVAC") troubleshooting and recovery	Med	Q1	Brian	Zach			

# Creating the Initial List of Tasks



# Top Benefits

- Creates a useful understanding with the stakeholders, and open for controlled changes.
  - Lets the stakeholders know what they can expect from the Systems Engineers and what they will get for the WBS budget.
- Helps manage the Systems Engineering Team by planning who is assigned to a particular task, as well as when it will be performed and completed.
- Informs the PDLs and Discipline Engineers who to approach within the SE team on a particular topic.

# Results:

- ✓ Quick and easy approval on the work package
  - ✓ Acquired the funding levels necessary do the job
  - ✓ Improved IPM & PDL alignment on key expectations for the SE WBS
  - ✓ Clear and traceable roles and expectations within the SE team
  - ✓ Data easily ports over to execution management
- Lower stress, better relationships, higher probability of mission success

Key Elements of Being Sustainable & Fulfilling

# Part 2 – Two Challenges We Faced as Systems Engineers and How We Responded

2a) Defining what a Systems Engineer does and what they're responsible for.

 2b) Working with others in different cultures, norms, customs, and expectations.

# International Cooperation is Important

- NASA chartered “to contribute materially to...cooperation by the United States with other nations and groups of nations,”

*National Aeronautics and Space Act of 1958*

- International cooperation can access science, data, and capabilities that wouldn't be available without that cooperation.
- I view international cooperation as a form of relationship building for the USA.
- “It's not easy to cooperate, but it's more difficult to succeed alone.”

*2013 ESA Director General Jean-Jacques Dordain*

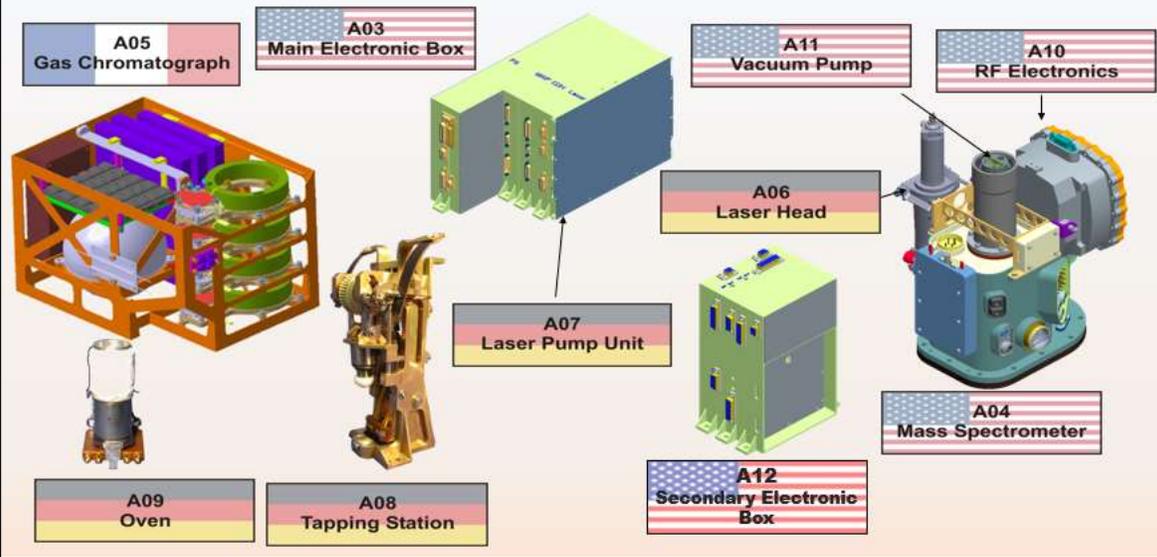


ESA Director General Jan Woerner and NASA Administrator Charlie Bolden

# Countries in the MOMA Instrument Partnership

# Countries in the ExoMars Mission

## MOMA Decomposition



### Russia

Khrunichev, Lavochkin Association, TsENKI

### United States

ATK-PSI, EMS, ERG, GD-DTS, Haigh-Farr, Honeywell, Mu Space

### Canada

MDA, Neptec

### Israel

Rafael

### Netherlands

Bradford, TNO, TNO-TPD, SSBV, Airbus DS-NL

### United Kingdom

ABSL, Airbus DS-UK, Fluid Gravity Engineering Ltd, Qinetiq, TAS, Tessella, Vorticity

### Belgium

ASTEK, DHB-BE, Qinetiq, TAS-BE, Trasy

### France

Airbus DS-FR, ETS, SAFT, Sauriau, TAS-F Cannes

### Switzerland

Almatech, APCO  
Clemessey, Maxon, RUAG

### Portugal

Active Space Technologies,  
Critical Software, Deimos,  
GMV, HPS, IST

### Spain

Casa, Crisa, Deimos, GMV, Iberespacio,  
Ryma, Senet, TAS-ES

### Finland

Patria, Space Systems

### Norway

Kongsberg

### Sweden

RUAG

### Denmark

Terma

### Poland

Senet

### Germany

Airbus DS-DE, Airbus DE, DLR, DSI, ETS,  
Gerling Holz & Co., Kayser-Threde, OHB,  
Rockwell Collins

### Austria

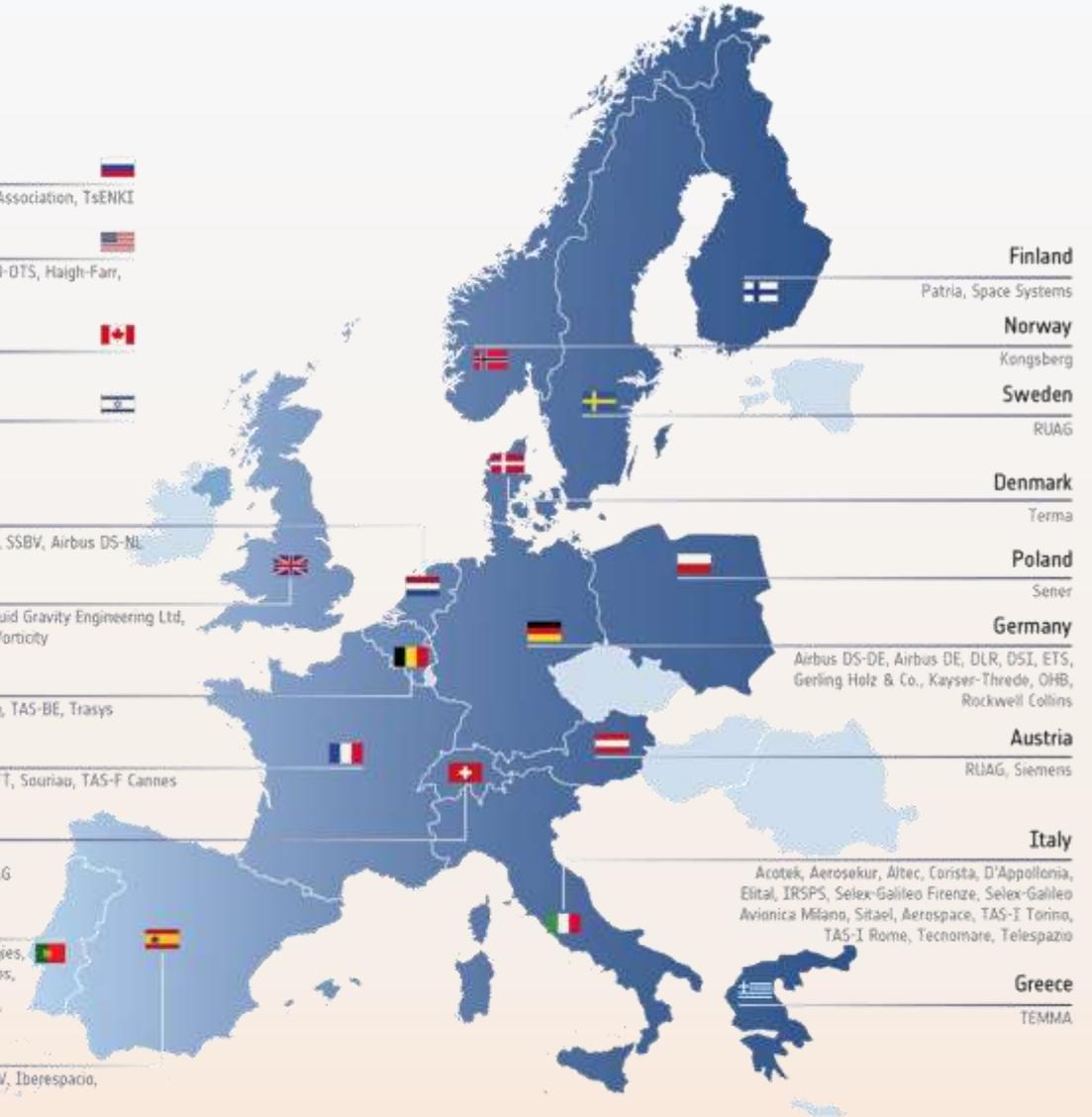
RUAG, Siemens

### Italy

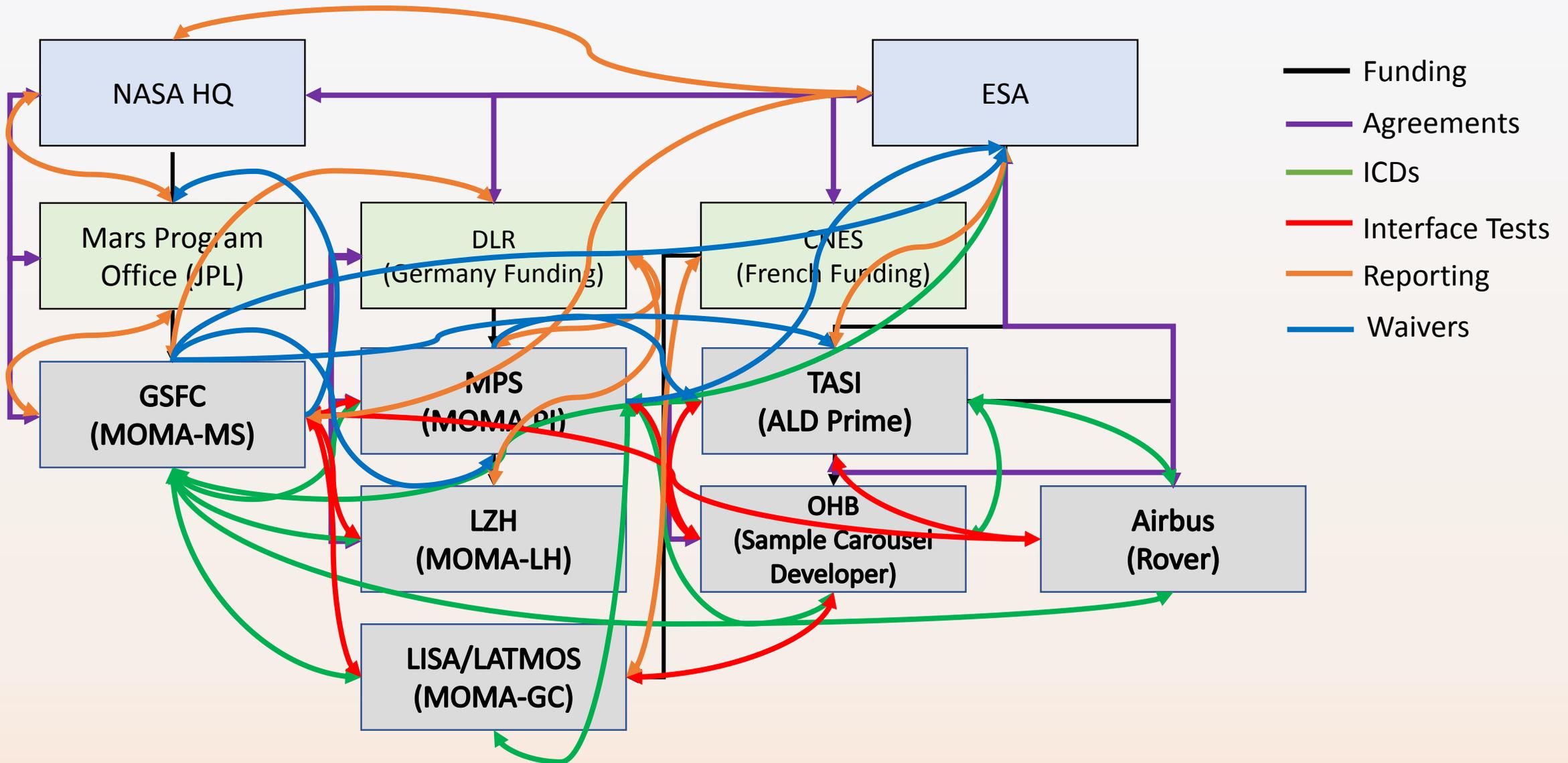
Acotek, Aerosekur, Altec, Corista, D'Appollonia,  
Elital, IRSPS, Selex-Galileo Firenze, Selex-Galileo  
Avionica Milano, Sital, Aerospace, TAS-I Torino,  
TAS-I Rome, Tecnomare, Telespazio

### Greece

TEMMA



# ExoMars Organization



# Biggest Challenges

- ESA design reviews are structured and focused much different.
- NASA & ESA management styles & processes have differences, including those related to technical management.
- ExoMars willing to take different kinds of risks than customary NASA missions.
- Different communication styles, forums, & philosophies.
- Verification and qualification strategies different than customary NASA ones.
- More instrument-driven leadership necessary on ExoMars than I'm accustomed to.
- Best practices can differ between Agencies.

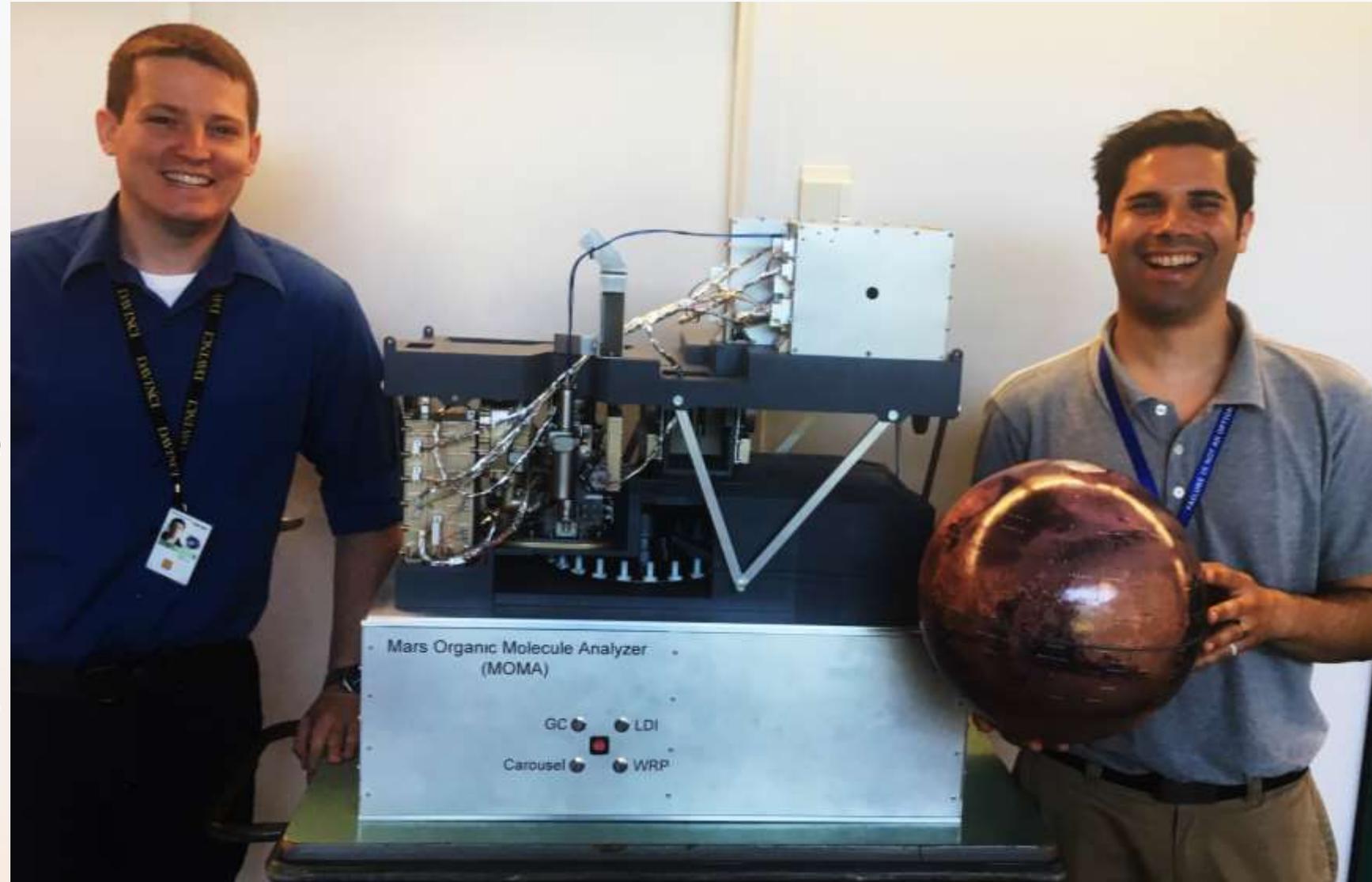
...and more

# What We Did Successfully

- Prepared and planned for disconnects.
- Sought to understand the functional drivers to our processes, so we could compare them to the European counterpart.
- Delegated leadership appropriately.
- Mutual trust from the GSFC organizations and their management.
- Appropriately managed risk for excessive delays in waiver/deviation approvals.
- Face-to-face communication, and the strengths that go along with it, were often employed.
- Prioritized interface validation tests.
- Aggressively used action item tracking to log & track open information needs from both sides

# Looking Back on 7 Years of MOMA Systems Engineering

- When MOMA-MS came to GSFC in 2010, we were inexperienced in Systems Engineering on med-high complexity developments.
- Getting to an on-time CDR was the toughest thing we've done in our career.
- Now in 2017, we see how the knowledge and expertise we gained makes us more productive, effective, and comfortable with the job.
- This again led to lower stress, better relationships, and higher probability of mission success. Again, key elements of being sustainable & fulfilling.



# When will MOMA get to Mars?

- Leadership transferred to GSFC in 2010
- Confirmed for the 2018 Launch Date in 2014
- Rebaselined for the 2020 Launch Date in 2017
- Flight Unit assembled and preparing for pre-environmental CPT
- Delivery March 2018
- Integration into the payload module
- Rover integration
- Launch July 2020
- 8 month cruise, 7 month surface operations





**STAY STRONG**



**MOMA INSTRUMENT DELIVERY IS COMING SOON!**

# **Backup Slides**