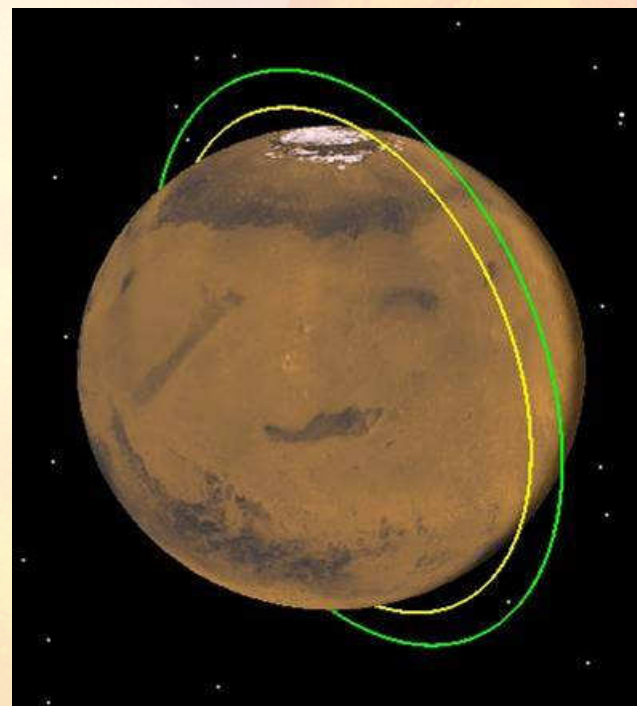




Report to MEPAG  
on the  
ESA-NASA  
Joint Instrument  
Definition Team (JIDT)  
for the Proposed  
2016 Orbiter-Carrier

July 29, 2009



*Presented by  
R. Zurek & A. Chicarro*



## *JIDT Membership*

### ESA Participants

- Augustin Chicarro
  - *ESA - Co-Chair*
- Jean-Loup Bertaux
  - *Service D'Aeronomie, CNRS*
- Frank Daerden
  - *BIRA/IASB*
- Vittorio Formisano
  - *IFSI Roma (I)*
- Gerhard Neukum
  - *Freie Universitaet Berlin*
- Albert Haldemann
  - *EXM/ESA*

### NASA Participants

- Rich Zurek
  - *JPL (MPO) - Co-Chair*
- Mark Allen
  - *JPL*
- R.Todd Clancy
  - *Space Science Institute*
- Jim Garvin
  - *NASA GSFC*
- Michael Smith
  - *NASA GSFC*
- Tom Komarek
  - *JPL (MPO)*



## ***Background***

- *January to June 2009:* NASA and ESA consider joint collaboration options that might enable implementation of the ExoMars (EXM) landed mission in the 2016 launch opportunity
  - EXM Project was already well into mission definition, with major descopes during this period to build mass margins
  - Define options for discussion at the ESA-NASA Bilateral Meeting June 29
  - Consider possible approaches to future Mars joint ventures
- *April to June 2009:* Assuming an orbiter/carrier that deploys EXM, consider what scientific observations might be conducted from orbit to address the objectives of a trace gas mission
  - Joint (Science) Instrument Definition Team formed (charter on next slide)
  - *Guidelines (April'09) to be assumed for a potential joint ESA-NASA mission:*
    - Would launch in 2016 with a 1200 kg (TBC) Descent Module
    - Would deploy the ExoMars Descent Module from a highly elliptical orbit in 2017 (prior to dust-storm season and at a season of high atmospheric pressure)
    - Would provide telecommunication relay for a 6-month EXM surface mission
    - Would aerobrake into a more circular orbit for science
    - Would provide relay for future landed missions past 2020



## ***Joint Instrument Definition Team (JIDT) Charter***

- What mission requirements (payload, orbit, data return) would be needed to implement a 2016 science orbiter mission focused on:
  - Detection of a broad suite of atmospheric trace gases
  - Characterization of their spatial and temporal variation
  - Localization of sources of key trace gases?
- These requirements should include discussion of
  - Payload: Instruments, mass, power, data rate, FOVs, observation cycles
  - Orbit: Inclination, altitude/period
- Endorse, reject, refine, and/or augment the inputs provided at the kick-off meeting (*largely based on the report and update to NASA by the Mars Science Orbiter Science Definition Team and reconsidered by the JIDT*). Key questions to be addressed:
  - Should/could (within resources) a mapping capability be included?
  - What are the observation modes that must be accommodated?
  - What would be the orbit requirements?
- Report out on May 4 (*later deferred to June 3*).
  - The report to be used as a baseline for a Joint Announcement of Opportunity for instruments on the 2016 joint orbiter/carrier.



## *JIDT Minimum Orbiter Trace Gas Objectives*

### **Detection:**

- Would require very high sensitivity to the following molecules and their isotopomers:  $\text{H}_2\text{O}$ ,  $\text{HO}_2$ ,  $\text{NO}_2$ ,  $\text{N}_2\text{O}$ ,  $\text{CH}_4$ ,  $\text{C}_2\text{H}_2$ ,  $\text{C}_2\text{H}_4$ ,  $\text{C}_2\text{H}_6$ ,  $\text{H}_2\text{CO}$ ,  $\text{HCN}$ ,  $\text{H}_2\text{S}$ ,  $\text{OCS}$ ,  $\text{SO}_2$ ,  $\text{HCl}$ ,  $\text{CO}$ ,  $\text{O}_3$
- Detection sensitivities of 1-10 parts per trillion

### **Characterization:**

- Spatial and Temporal Variability: Latitude-longitude coverage multiple times in a Mars year to determine regional sources and seasonal variations (reported to be large, but still controversial with present understanding of Mars gas-phase photochemistry)
- Correlation of concentration observations with environmental parameters of temperature, dust and ice aerosols (potential sites for heterogeneous chemistry)

### **Localization:**

- Mapping of multiple tracers (e.g., aerosols, water vapor,  $\text{CO}$ ,  $\text{CH}_4$ ) with different photochemical lifetimes and correlations helps constrain model simulations and points to source/sink regions
- To achieve the spatial resolution required to localize sources might require tracing molecules at the  $\sim 1$  part per billion concentration
- Inverse modeling to link observed concentration patterns to regional transformations (e.g., in dusty air) and to localized sources would require simulations using circulation models constrained by dust and temperature observations



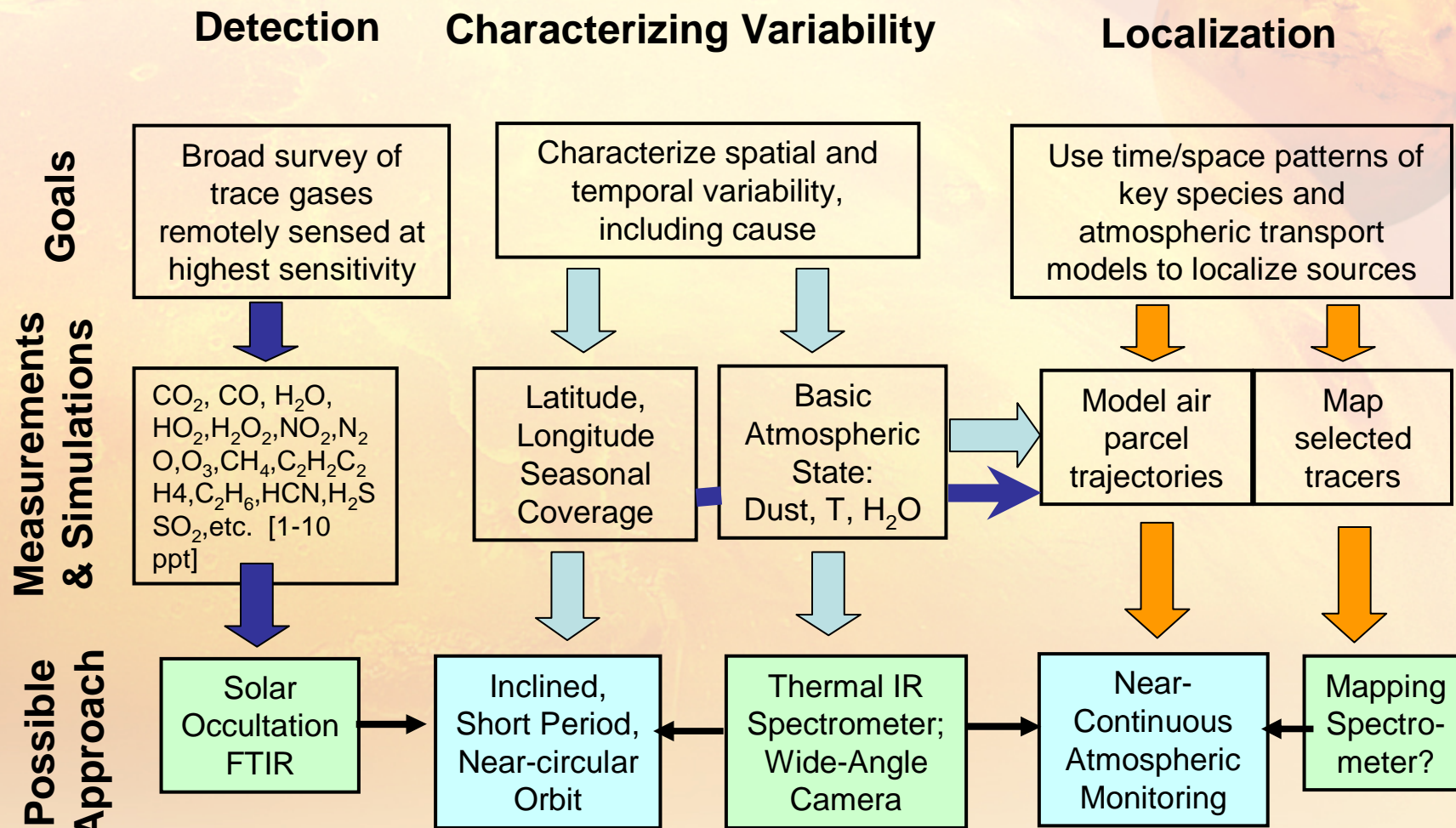
## ***What Science Questions are Raised by Methane Detection?***

**Current photochemical models cannot explain the presence of methane in the atmosphere of Mars and its reported rapid variations in space and time. Neither appearance nor disappearance can be explained, raising the following scientific questions:**

- Is there ongoing subsurface activity?
  - Are there Surface/near-Surface Gas Reservoirs (particularly ice)? Where are they?
- What is the nature of gas origin: geochemical or biochemical?
  - Are other trace gases present? What are the isotopic ratios?
- What processes control the lifetimes of atmospheric gases?
  - Time scales of emplacement or activation and modification (seasonal, annual, episodic, longer term)
  - Role of heterogeneous chemistry
  - Atmospheric-surface interactions



# Trace Gas Science Requirement Flow-Down





# Key Science Requirements on Proposed Orbiter\*

*(Developed by NASA-ESA EWG, Presented at 1<sup>st</sup> JIDT April 17, 2009)*

Requirement	Value
Science Payload Mass (Trace Gas + Nadir/Limb)	70 kg
Science Payload Power	50W orbital average, 70W sustained during TG detection events
Orbital Period/Number of Trace Gas Detection Observations	400 km near-circular altitude/Near 2 hours (>20 observations per day)
Orbital Inclination/Distribution of Trace Gas Observations	74° ± 10° or mirror image (106° ± 10°) [Yields wide range of latitudes & solar beta angles]; EXM preferred 64° retrograde.
Nadir/Limb Observations	Near-continuous observation of atmosphere between occultations (including during data return); might require gimbals or instrument platform
Science Payload Data Volume	80 Mbits/Occultation (Trace Gas)* + ~400 Mbits/day (Nadir/Limb Observations) [ <i>*Note 1: Assumes onboard data processing internal to the instrument – data rate from instrument to bus to be negotiated after instrument selection</i> ]; might require HGA gimbal
Science Payload Pointing	1 mrad control during occultation observations, with 0.3 mrad knowledge. Stability 0.3 mrad over 240 secs.
Fields of view	To be negotiated, but Trace Gas detection instrument expected to have sensitive radiator face in addition to observation aperture (instrument self-cooled to < 100K, typically 2-stage cooler)
Total Science Observation Phase	1 Martian year (follows EXM deployment & 6-month surface mission plus aerobraking; begins in 2018)

*\*For NASA, this is subject to confirmation based on instruments selected via AO Competitive process*





## ***Instrument Acronyms***

***The following are a “short-hand or existence proof” for instrument measurement capabilities. Should a mission go forward, the actual payload would be selected through an AO.***

- TG-D: Trace Gas Detector (solar occultation; high spectral resolution across broad spectral interval; high data rate [onboard processing?])
  - FTIR: Fourier Transform IR Spectrometer used as representative
- TG-M: Trace Gas Mapper (moderate spectral resolution across selectable spectral intervals; might combine nadir, limb and/or occultation viewing)
- TIR: Thermal IR Imager (views atmospheric thermal emission--sensitive to presence of dust)
- Sub-mm: Sub-millimeter/microwave spectrometer or equivalent (views atmospheric thermal emission--passive sounder not affected by presence of dust)
- WAC: Wide Angle Camera (provides frequent/global views of atmospheric phenomena and surface change)
- HRSCC: High Resolution Stereo Color Camera (~2 m/pixel, near-simultaneous stereo, color discrimination of water ice, dust and surface variations)



## 2016 Proposed Measurement Objectives

*\*Example concepts serving as shorthand for required measurement capabilities*

<b>Science Measurement Goals</b> Shown in priority order.	<b>Lead Instrument Capability*</b> Contributing Instrument
<b>Trace Gas /Aerosol - Detection</b> Global, seasonal, time-of-day vertical profile sampling of a suite of potential Mars trace gases	FTIR TGM/SOIR, Sub-mm, TIR
<b>Trace Gas - Mapping</b> Latitude-longitude coverage of selected trace gases using a combination of column, nadir profile, limb and/or solar occultation observations.	TG-M FTIR, Sub-mm, TIR
<b>Aerosols (ice &amp; dust)</b> Vertical profiles & horizontal coverage of aerosol concentration	TIR WAC
<b>Temperature</b> Vertical profiles and horizontal coverage of atmospheric temperature	Sub-mm TIR
<b>Weather Systems (e.g., dust storms)</b> Daily global coverage of atmospheric clouds/hazes	WAC HRSCC
<b>Geologic Context &amp; Surface Change</b> Imaging of potential trace gas sources; detection of surface change	HRSCC Previous Imaging (MRO CTX, HiRISE; MEX HRSC)



## *Key Findings*

- Trace Gas Detection and Mapping (Localization) both would be essential to achieving the proposed science goals and both are high priority.
- Aerosol and temperature correlation would be required to understand processes changing trace gas concentrations (transport, homogeneous and heterogeneous chemistry).
- Atmospheric and surface context are important.
- 70 kg must be considered a minimum (w/o margins) payload mass
  - Anything less would lead to a scientifically incomplete (therefore compromised) mission necessitating a follow-on mission
  - Should look at whether there are other resources (inclination change?) that could be traded for payload mass.
  - While a case could be made for 1-2 m/pixel visible imaging, such a system would not fit within a 70 kg payload allocation.
- A mixture of limb and nadir viewing and solar occultation would be required to achieve the science goals.
- Observations are desirable during relay support and, if possible, prior to Descent Module release (~ 1 to 2 year period)



# Key Science Requirements on Proposed Orbiter\*

*(Requirements based on JIDT input, June 2009)*

Requirement	Value
Science Payload Mass (Trace Gas + Nadir/Limb)	<b>115 kg (including margins, but not a high-resolution camera)</b>
Science Payload Power	<b>~140 W (including margins)</b>
Orbital Period/Number of Trace Gas Detection Observations	400 km near-circular altitude/Near 2 hours (>20 observations per day)
Orbital Inclination/Distribution of Trace Gas Observations	74° ± 10° or mirror image (106° ± 10°) [Yields wide range of latitudes & solar beta angles]; EXM preferred 64° retrograde. <b>Potential Mass Trade</b>
Nadir/Limb Observations	Near-continuous observation of atmosphere between occultations (including during data return); might require gimbals or instrument platform
Science Payload Data Volume	80 Mbits/Occultation (Trace Gas)* + ~400 Mbits/day (Nadir/Limb Observations) [ <i>*Note 1: Assumes onboard data processing internal to the instrument – data rate from instrument to bus to be negotiated after instrument selection</i> ]; might require HGA gimbal
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