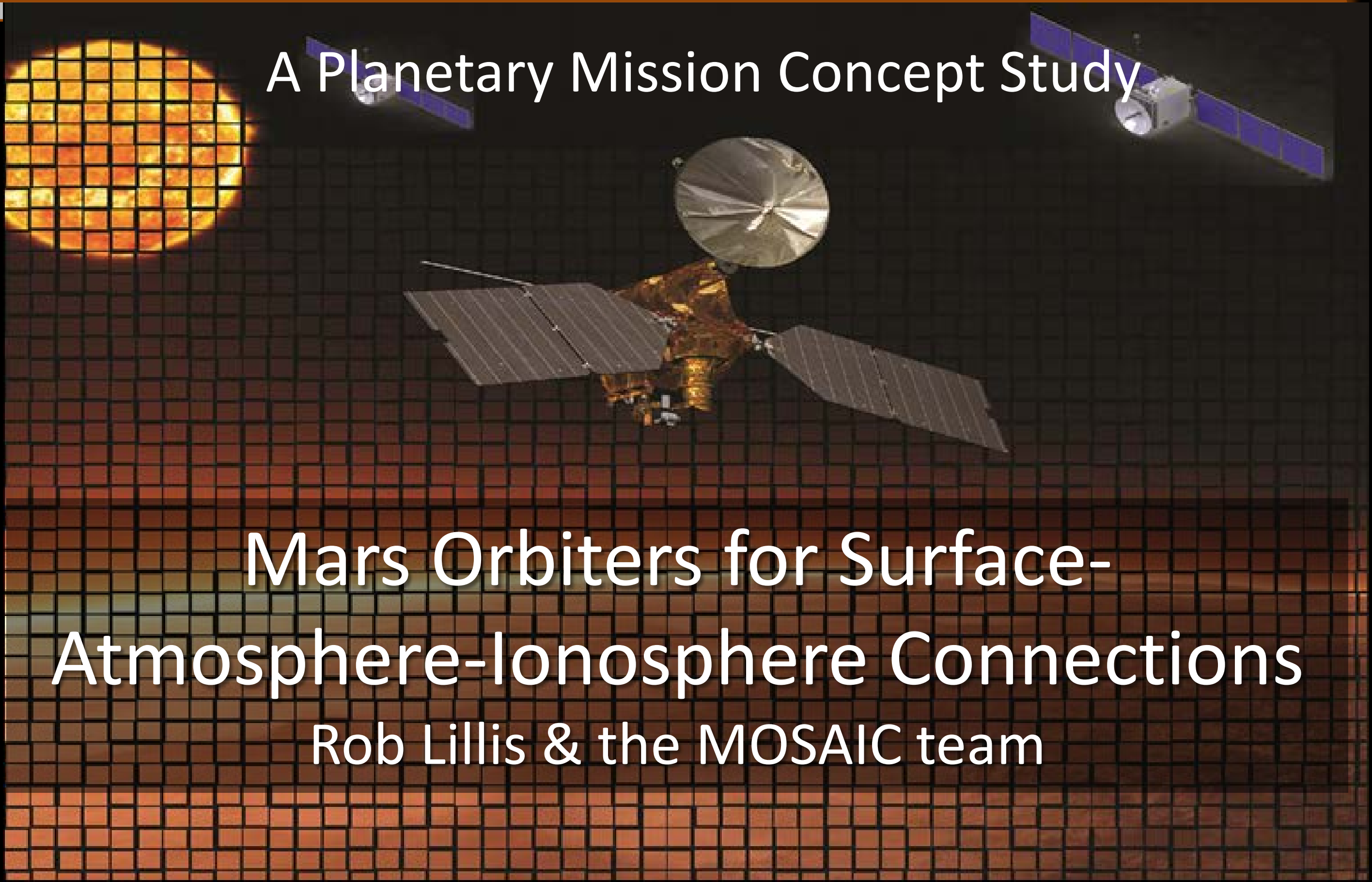
MOSAIC



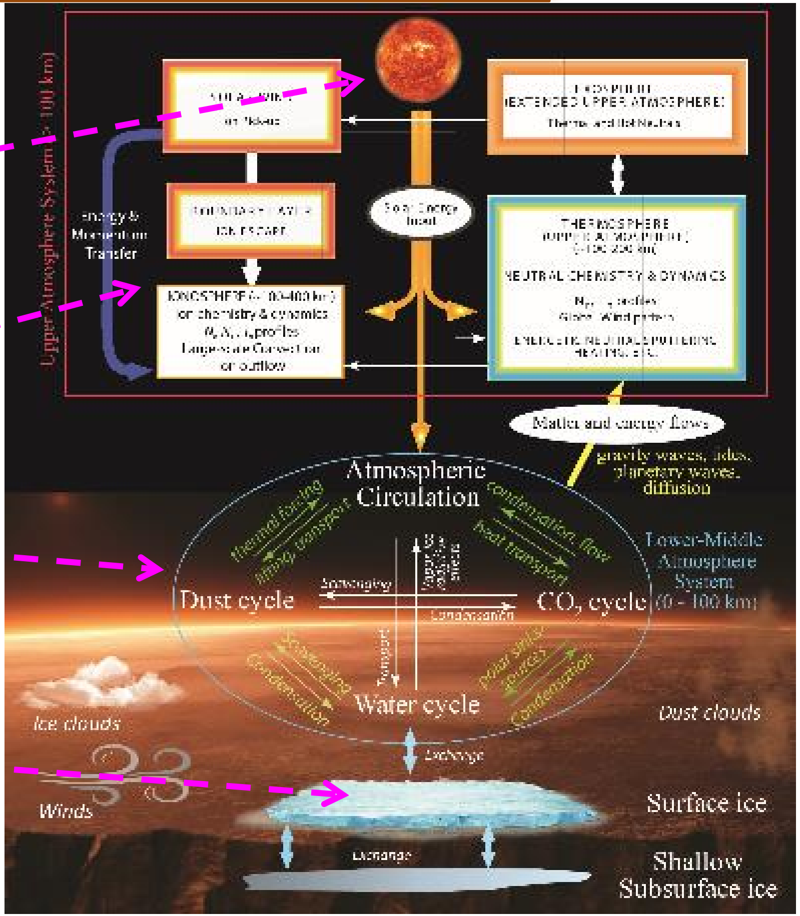
A Planetary Mission Concept Study

Mars Orbiters for Surface-Atmosphere-Ionosphere Connections

Rob Lillis & the MOSAIC team

MOSAIC Goals & Objectives: Science

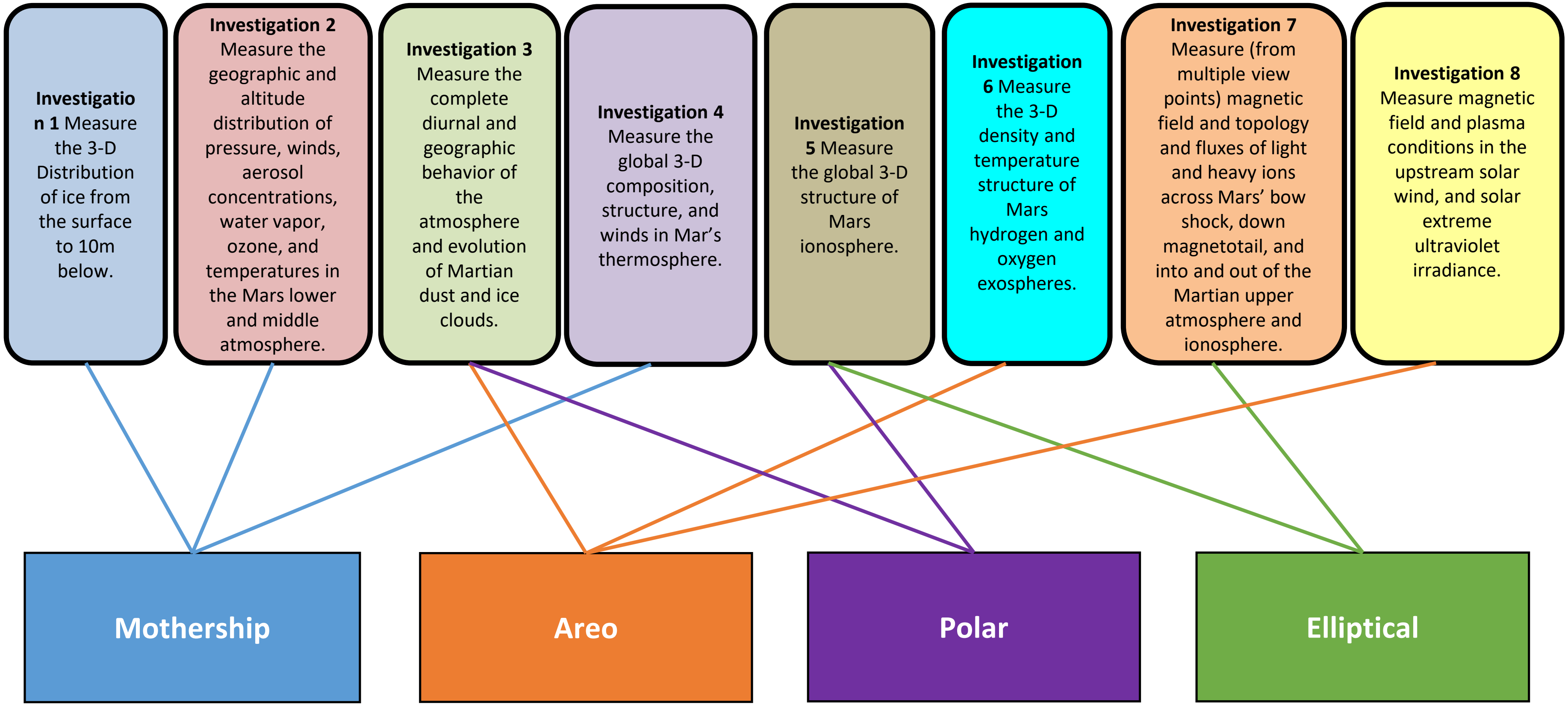
MOSAIC GOALS	Mission Objectives	
Understand Mars's present day climate processes and their inter-connections, from the sub-surface to the solar wind *(i.e. how do the different parts of the Mars climate system talk to each other?)*	I.D Characterize fields and plasma flows in the upstream solar wind and throughout the magnetosphere and upper ionosphere, separating spatial from temporal variability.	
	I.C: Correlate variability in the thermosphere, ionosphere, and escape rates to:	Conditions in the lower-middle atmosphere.
		The space weather environment
	I.B: Characterize the structure and dynamics of the Martian lower-middle atmosphere on meso- and global scales, and its geographic, diurnal, and seasonal variability.	
	I.A: Characterize volatile cycling between the subsurface, surface and atmospheric reservoirs.	



Objectives to Investigations

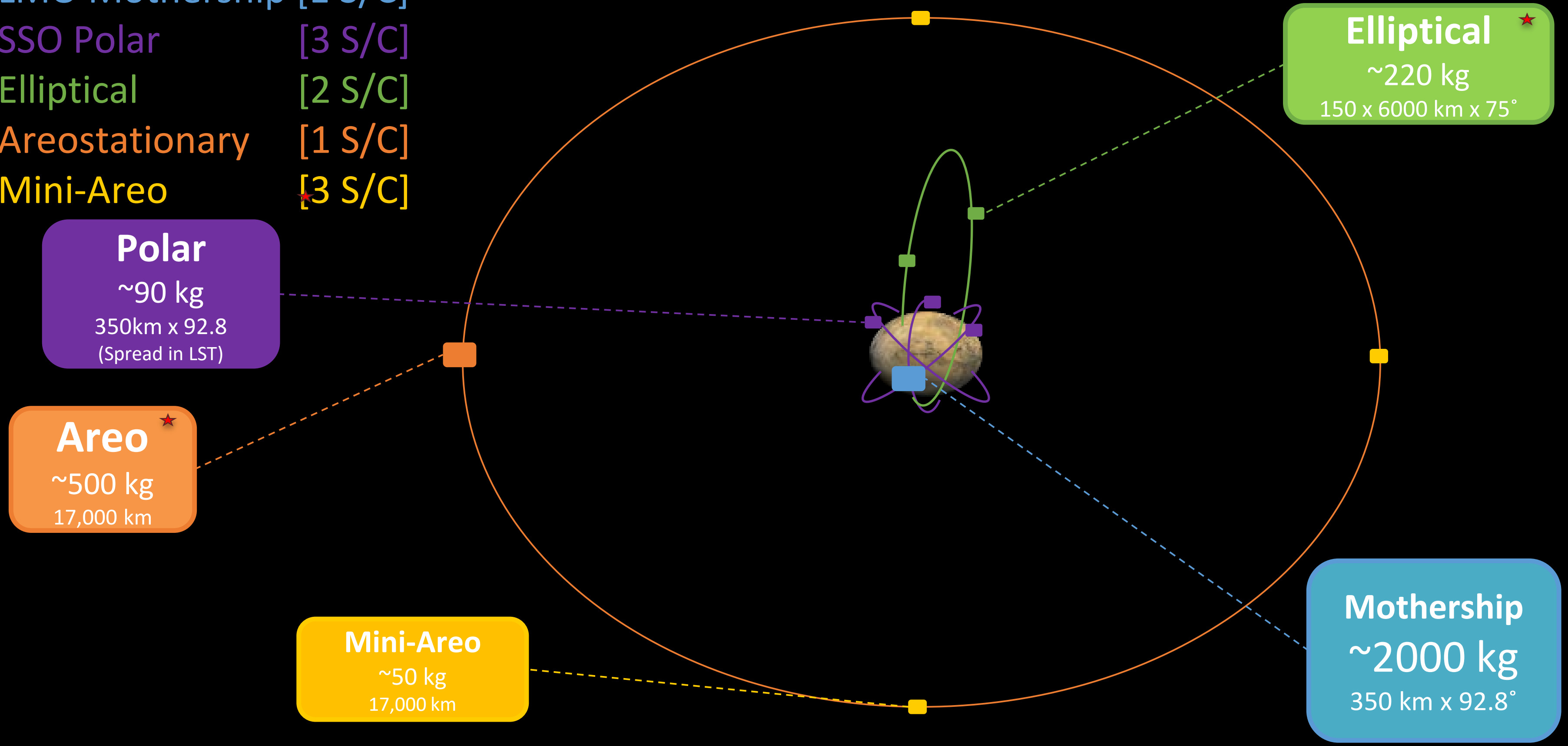
Mission Objectives	Investigations:	1. Ice distribution	2. Atmosphere structure	3. Atm. Diurnal behavior	4. Thermosphere	5. Ionosphere	6. Exosphere, neutral escape	7. Plasma & ion escape	8. Space weather
I.A: Characterize volatile cycling between the subsurface, surface and atmospheric reservoirs.		✓	✓	✓					
I.B: Characterize the structure and dynamics of the Martian lower-middle atmosphere on meso- and global scales, and its geographic, diurnal, and seasonal variability.			✓	✓					
I.C: Correlate variability in the thermosphere, ionosphere, and escape rates to:	Conditions in the lower-middle atmosphere.		✓	✓	✓	✓	✓	✓	
	The space weather environment				✓	✓	✓	✓	✓
I.D Characterize fields and plasma flows in the upstream solar wind and throughout the magnetosphere and upper ionosphere, separating spatial from temporal variability.						✓	✓	✓	✓

Connections between science and architectures



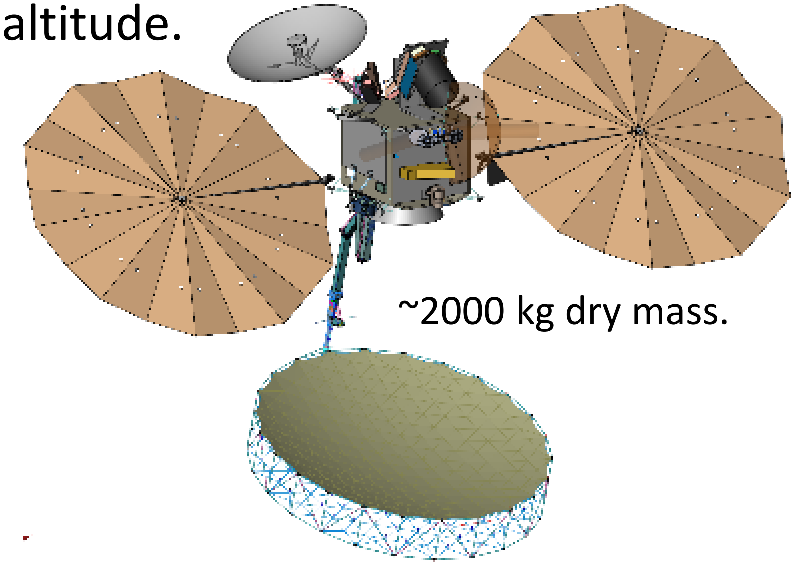
The MOSAIC Constellation

1. LMO Mothership [1 S/C]
2. SSO Polar [3 S/C]
3. Elliptical [2 S/C]
4. Areostationary [1 S/C]
5. Mini-Areo [3 S/C]



Mothership Platform

- **Measures vertical profiles at fixed local time of:**
  - **Subsurface ice**
  - **Lower/middle atmosphere: Temperature, pressure, H2O, aerosols and wind**
  - **Upper atmosphere: neutral composition& density, ion density, neutral wind**
- Large SEP Class B spacecraft. Low circular sun-synchronous polar orbit, ~350 km altitude.

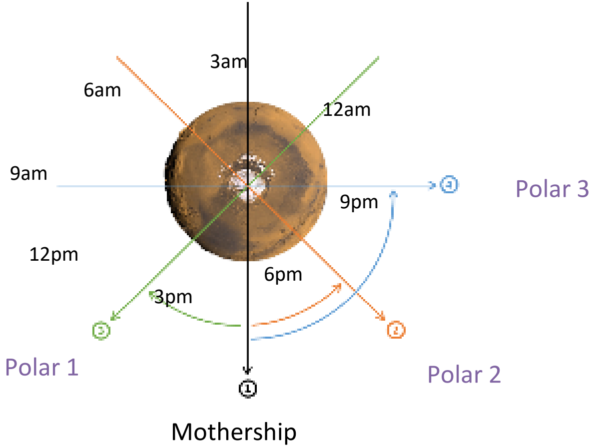


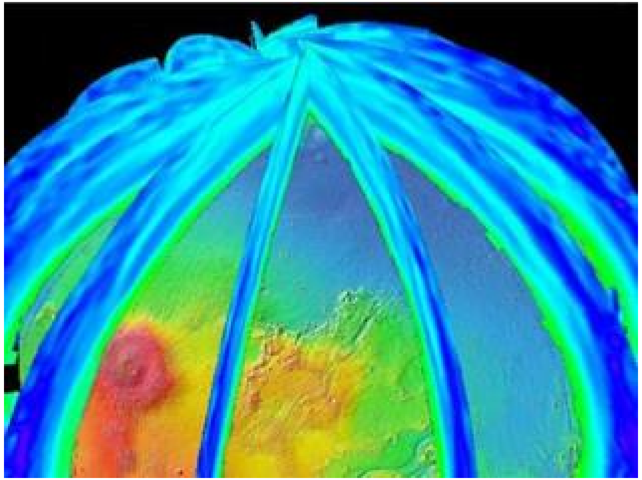
~2000 kg dry mass.

Instrument	Inv	Priority		Mass	Power	FY20 Cost
P-band SA radar	1	T : 1	B : 1	125 kg	200 W	$170 M
Visible camera	1	T : 1	B : 1	3.4 kg	10 W	$5 M
Thermal IR radiometer (MCS)	2	T : 1	B : 1	9 kg	18 W	$25 M
Wind LIDAR (MARLI)	2	T : 1	B : 1	45 kg	91 W	$40 M
Sub-mm sounder	2	T : 1	B : 1	35 kg	39 W	$35 M
Near IR spectrometer	3	T : 0	B : 1	0.3 kg	2.5 W	$0.34 M
Wind doppler interferometer	4	T : 1	B : 1	40 kg	20 W	$40 M
FUV/MUV spectrometer	4	T : 1	B : 1	27 kg	28 W	$30 M
Radio occultation	3,5	T : 1	B : 1	1.5 kg	3 W	$2 M
Total				**286 kg**	**412 W**	**$347 M**

Polar Orbit Smallsat

- **Measures: vertical profiles of pressure, temperature, water vapor, aerosols, iceand ionospheric plasma density.**
- Sun-synchronous low ~350 km polar orbit, 3-axis stabilized
- 3 copies of this spacecraft, each at a different local solar time
- Dropped off by the Mothership in a low polar orbit, and then moves itself into a sun-sync orbit with the correct local time

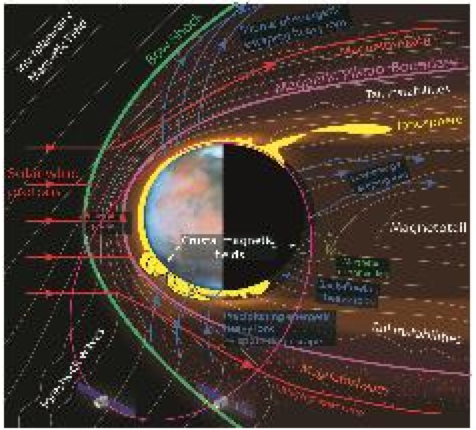


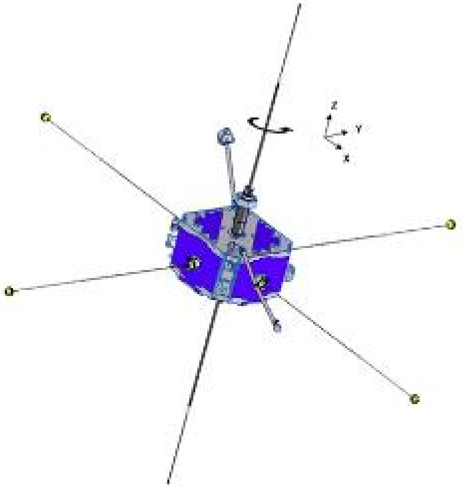


Instrument	Inv.	Priority		Mass	Power	Cost
Mini therm. IR radiometer	3	T : 1	B : 3	3.5 kg	8 W	$10 M
Mini near IR spectrometer	3	T : 0	B : 3	0.3 kg	2.5 W	$0.34 M
Radio occultation	3,5	T : 1	B : 3	1.5 kg	3 W	$2 M
Total				**5.3 kg**	**13.5 W**	**$12.3 M**

Elliptical Orbit Smallsat

- **Measures: ion and sputtering escape, magnetic morphology and topology, thermal plasma, and electric fields. Also neutral temperature/pressure via RO.**
- 2 copies, pearls-on-a-string orbit allows disambiguation of spatial/temporal variability and measurement of real-time response to solar storms.
- Elliptical orbit, 7000 km x 150km, 4.5 hours. Spinner.
- Booms, including four 20m centrifugally stabilized wire booms
- Dropped off by the Mothership in a near-polar elliptical orbit.
- Smaller cheaper non-spinning version without electric fields also examined.

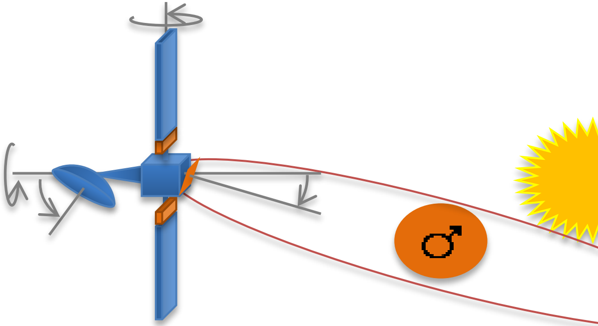


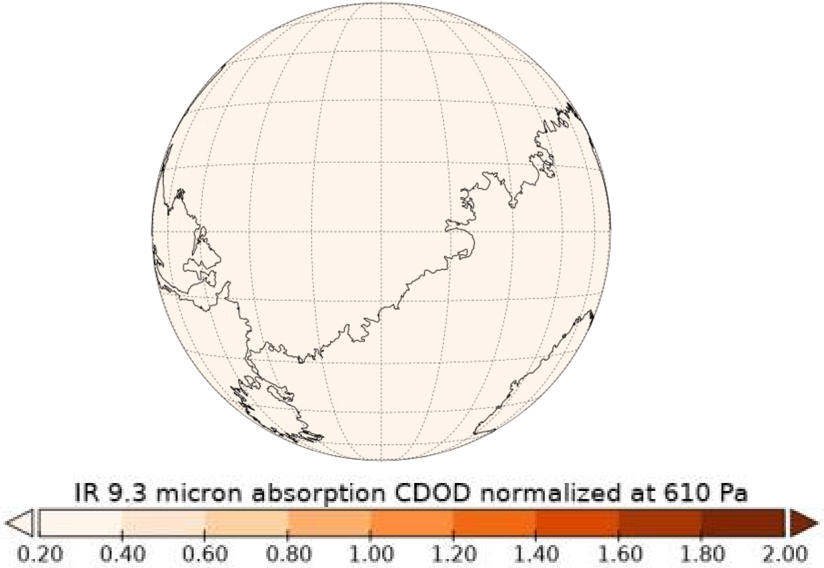


Instrument	Inv	Priority		Mass	Power	Cost
Fluxgate magnetometer	7	T : 2	B : 2	1.3 kg	4.9 W	$4 M
Ion energy/angle/mass	7	T : 2	B : 2	3.3 kg	4.2 W	$4 M
Electron energy/angle	7	T : 2	B : 2	1.8 kg	1.6 W	$3 M
Electric fields	7	T : 0	B : 2	12 kg	0.24 W	$2 M
Search coil magnetometer	7	T : 0	B : 2	1.8 kg	0.1 W	$3 M
Langmuir probe	5	T : 2	B : 2	0.45 kg	1.5 W	$0.5 M
Radio occultation	3,5	T : 2	B : 2	1.5 kg	3 W	$2 M
Total				**22.2 kg**	**15.5 W**	**$18.5 M**

Areostationary Spacecraft

- **Measures: 1) synoptic view of lower atmosphere (dust & ice column, ozone, temperature profile), 2) neutral oxygen and hydrogen escape rates 3) upstream space weather environment,.**
- Separates shortly after launch, goes to Areostationary orbit using SEP
- Solar arrays co-pointed with solar instruments.
- Mars-pointed instruments: Camera to Mars center; rest need to scan.





Instrument	Inv	Priority		Mass	Power	Cost
Visible camera (MSSS)	3	T : 1	B : 4	1.6 kg	7 W	$0.5 M
Mini therm. IR radiometer	3	T : 1	B : 4	3.5 kg	8 W	$10 M
Mini near IR spectrometer	3	T : 1	B : 4	3 kg	15 W	$2 M
FUV/EUV spectrograph	6	T : 1	B : 1	21 kg	12 W	$20 M
Fluxgate magnetometer	8	T : 1	B : 2	1.3 kg	4.9 W	$4 M
Ion energy/angle	8	T : 1	B : 2	2.6 kg	2.1 W	$3 M
Electron energy/angle	8	T : 0	B : 2	1.8 kg	1.6 W	$3 M
Energetic ion/electron	8	T : 1	B : 2	0.9 kg	5.5 W	$0.8 M
Extreme UV monitor	8	T : 1	B : 2	1.1 kg	0.7 W	$2 M
Total				**46.8 kg**	**57 W**	**$43.6 M**

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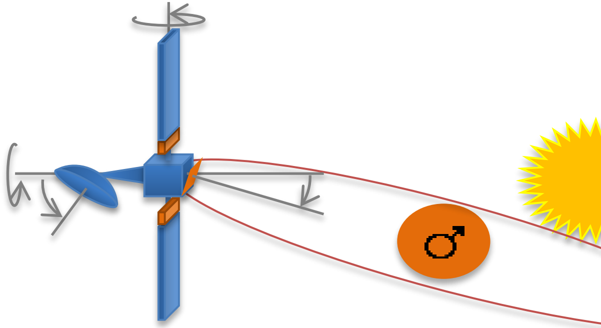

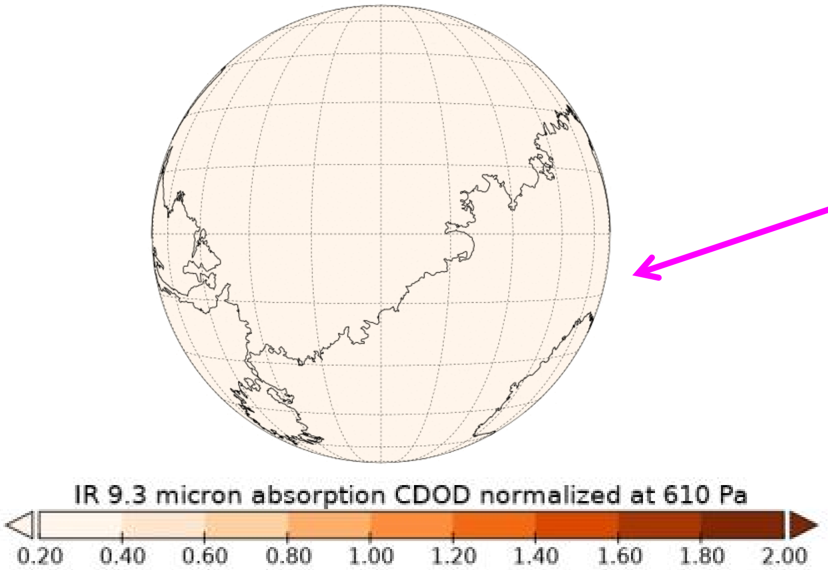

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Ion energy/angle	8	T : 1	B : 2	2.6 kg	2.1 W	$3 M
Electron energy/angle	8	T : 0	B : 2	1.8 kg	1.6 W	$3 M
Energetic ion/electron	8	T : 1	B : 2	0.9 kg	5.5 W	$0.8 M
Extreme UV monitor	8	T : 1	B : 2	1.1 kg	0.7 W	$2 M
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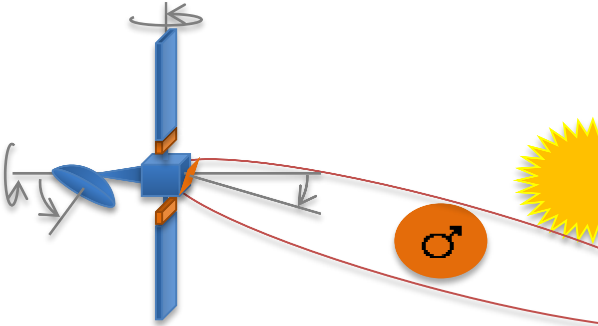

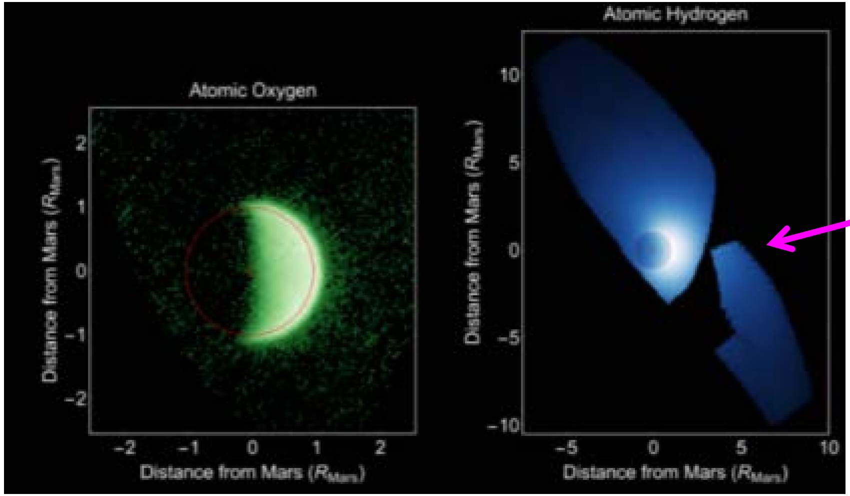

Instrument	Inv	Priority		Mass	Power	Cost
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Mini near IR spectrometer	3	T : 1	B : 4	3 kg	15 W	$2 M
FUV/EUV spectrograph	6	T : 1	B : 1	21 kg	12 W	$20 M
Fluxgate magnetometer	8	T : 1	B : 2	1.3 kg	4.9 W	$4 M
Ion energy/angle	8	T : 1	B : 2	2.6 kg	2.1 W	$3 M
Electron energy/angle	8	T : 0	B : 2	1.8 kg	1.6 W	$3 M
Energetic ion/electron	8	T : 1	B : 2	0.9 kg	5.5 W	$0.8 M
Extreme UV monitor	8	T : 1	B : 2	1.1 kg	0.7 W	$2 M
Total				**46.8 kg**	**57 W**	**$43.6 M**

Areostationary Spacecraft

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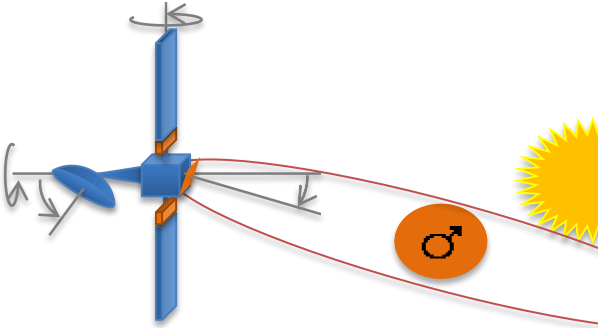

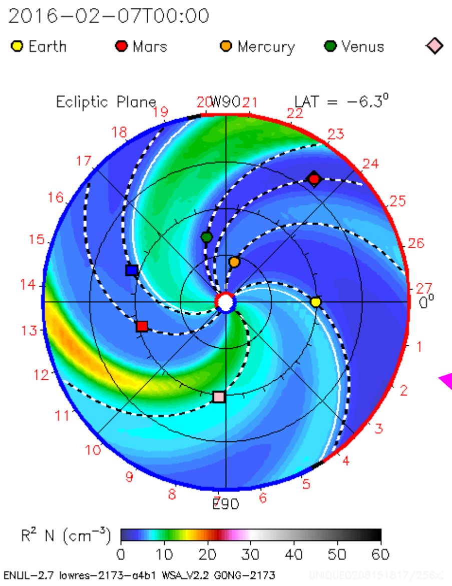

Instrument	Inv	Priority		Mass	Power	Cost
Visible camera (MSSS)	3	T : 1	B : 4	1.6 kg	7 W	$0.5 M
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Mini near IR spectrometer	3	T : 1	B : 4	3 kg	15 W	$2 M
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Electron energy/angle	8	T : 0	B : 2	1.8 kg	1.6 W	$3 M
Energetic ion/electron	8	T : 1	B : 2	0.9 kg	5.5 W	$0.8 M
Extreme UV monitor	8	T : 1	B : 2	1.1 kg	0.7 W	$2 M
Total				**46.8 kg**	**57 W**	**$43.6 M**

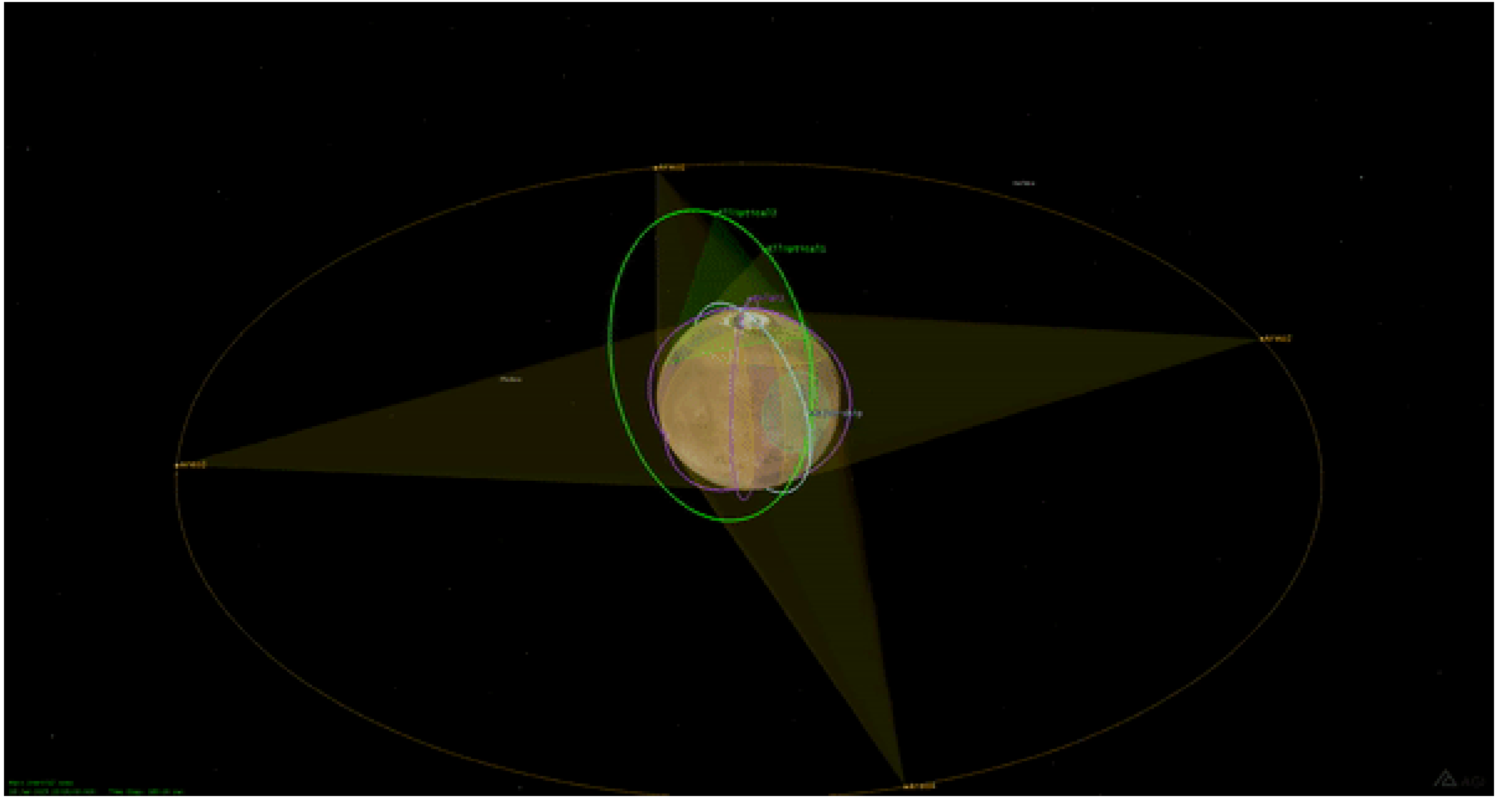
Descoped Mothership option

MOSAIC

- Preserves constellation aspect, global/diurnal coverage, and lower-upper atmosphere connection.
- Loses all the newest measurements: wind and ice. But ***significantly*** cheaper.

Instrument	Inv	Priority		Mass	Power	FY20 Cost
Visible camera	1	T : 1	B : 1	3.4 kg	10 W	$5 M
Thermal IR radiometer (MCS)	2	T : 1	B : 1	9 kg	18 W	$25 M
Near IR spectrometer	3	T : 0	B : 1	0.3 kg	2.5 W	$0.34 M
FUV/MUV spectrometer	4	T : 1	B : 1	27 kg	28 W	$30 M
Radio occultation	3,5	T : 1	B : 1	1.5 kg	3 W	$2 M
Total				**40 kg**	**62 W**	**$62 M**

MOSAIC Constellation Movie



Note: embedded movie wouldn't play. Had to resort to lower resolution GIF.

MOSAIC Goals & Objectives: Exploration

MOSAIC GOALS	**Mission Objectives**
II. Identify hazards, characterize resources, and demonstrate technologies to enable the Human Exploration of Mars.	II.A: Characterize potentially extractable water ice resources to support in situ resource utilization
	II.B: Characterize the Mars atmospheric state with sufficient spatial sampling and cadence to allow accurate data assimilation and weather forecasting.
	II.C: Characterize the Mars ionospheric state and variability sufficiently to determine its likely disruptive effect on communications and positioning
	II.D: Demonstrate delay-tolerant networking and relay communication between Mars surface, Mars orbit, and Earth.
	II.E: Demonstrate high-bandwidth deep space communication between Earth and Mars.

MOSAIC 30-second summary

MOSAIC

- ***What?*** *"MOSAIC will unveil the complete Martian climate system, from meso- to planetary scales and from subsurface to exosphere, while enabling hazard forecasting, communication, and resource prospecting for human exploration."*
- ***Why?***
  - *A) The interconnections between the surface, lower and upper atmospheres, and ionized environment, are stronger than previously thought and poorly understood.*
  - *B) Martian explorers will need water, air, fuel, weather forecasts and comms.*
- ***How?*** *5-10 coordinated satellites making simultaneous measurements of Mars' climate system, many for the first time.*
- ***When?*** *post-2028*
- ***How much?*** *We'll tell you soon but $1-3B*
- ***Are you crazy?*** *Quite possibly. We'll see.*


Thank you

Backup slides

MOSAIC org chart

MOSAIC

Science Team

Thermosphere - Inv. 4, 8
Lead: **S. England**
J. Deighan, S. Bougher, A. Brecht

Magnetosphere/Escape - Inv. 7,8
Lead: **S. Curry**
J. Luhmann, **D, Mitchell**, F. LeBlanc, J. Halekas, D. Brain, X. Fang, J. Espley, H. Opgenoorth, O. Vaisberg

Upper-Lower Atmosphere Connections - Inv. 2-8
Lead: **M. Chaffin**
S. England, B. Jakosky, A. Brecht, J. Deighan, F. Forget, S. Bougher
Leads: R. Lillis, D. Mitchell

Subsurface & Surface Ice - Inv. 1
Lead: **T. Harrison**
C. Neish, I. Smith, G. Osinski, C. Stuurman, S. Spencer.

Lower-Middle Atmosphere – Inv. 2, 3
Leads: **L. Montabone, S. Guzewich**
M. Kahre, **N. Heavens**, M. Smith, A. Spiga, M. Mischna, M. Wolff, A. Kleinboehl, D. Hinson, F. Forget, L. Tamppari, B. Cantor

Comms, Radio Science - Inv. 2, 3, 5, 9
Lead: **C. Ao**
P. Withers, J. Vander Hook, D. Hinson, O. Karatekin, S. Asmar, M. Van Woerkum

Ionosphere - Inv. 5, 7, 8, Lead: P. Withers
R. Lillis, D. Andrews, M. Paetzold, S. Tellmann, K. Peter, C. Fowler, M. Lester, B. Sanchez-Cano

JPL Study Team

Lead: **S. Matousek**, Systems: **Nathan Barba**, Mission design: **Ryan Woolley**
Plus lots of JPL folks from A-Team, Team-X, and Team-Xc

PMCS Study Plan/schedule

MOSAIC

1. Define Science Requirements (10-11/19) ✓
2. Define Instrument Requirements (11-12/19) ✓
3. JPL A-Team Session I: building blocks (12/17/19) ✓
4. Science Team meeting Berkeley (01/27/20) ✓
5. JPL A-Team Session II: narrow architecture (02/5-6/20) ✓
6. JPL Team Xc Smallsat Designs & Cost (02/18-26/20) ✓
7. LPSC Progress Report (03/15/20) ✓
8. JPL Team X Point Design & Cost (03/31 – 04/03/20) ✓
9. Writing.
10. Final report July 2020.