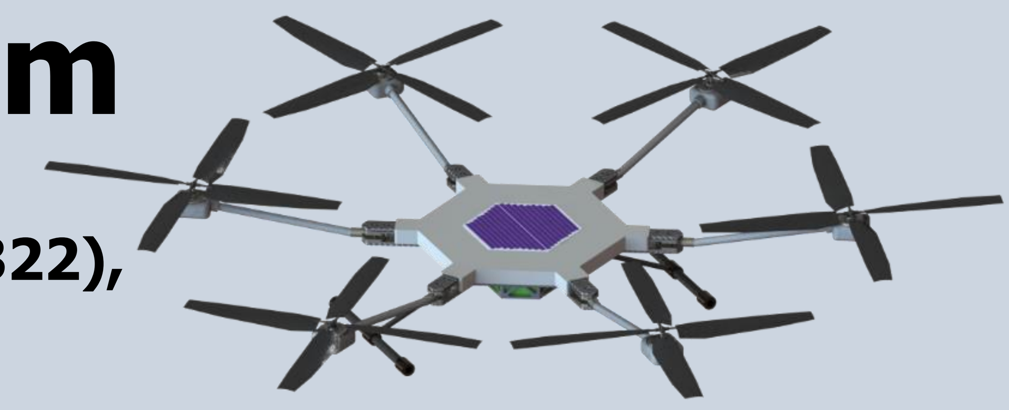
National Aeronautics and Space Administration

Mars Science Helicopter System

Principal Investigator: Teddy Tzanetos (347)

Gerik Kubiak(347), Wayne Johnson (NASA ARC), Timothy J. Parker(322), Jon Bapst(322), Luis Phillipe C. Tosi(347), Havard F. Grip(343)

Program: Strategic Initiative



Project Objective:

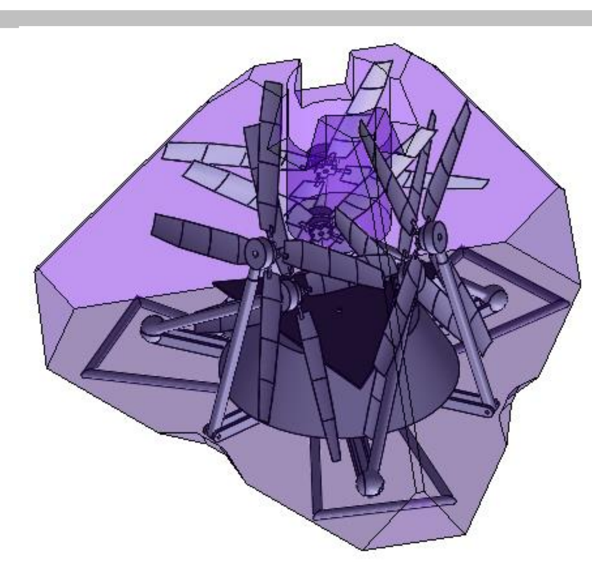
- Design, build, and deploy a science-driven, instrumented future Mars Science Helicopter (MSH), capable of delivering science payloads in the **2-4 kg** class to the frontiers of Mars.
- Canonical MSH Design, Size, Weight, Power tradeoff analysis
- Earthbound Demonstrator
  - FSW & Autonomy
  - Science Payload Integration
- Field Test Campaigns to test autonomy and con-ops for an airborne science platform.

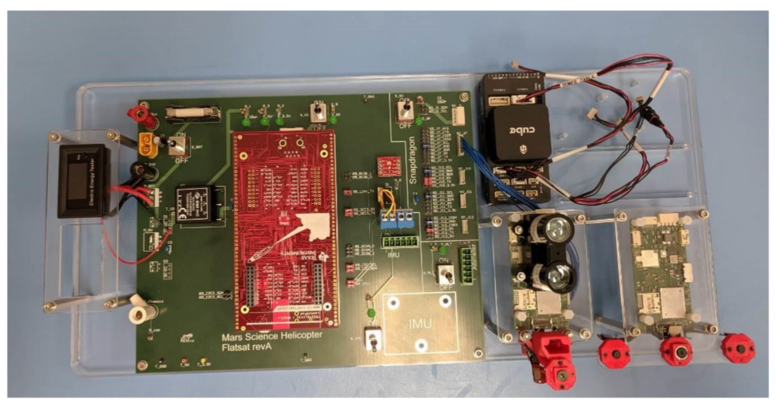
FY18/19 Results:

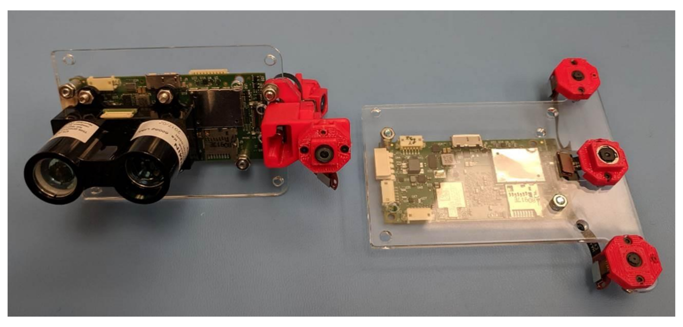
- **MSH Canonical Design**: Analyzed scaled coaxial and multicopter designs capable of carrying 1-4kg of science payloads for ~7 minutes on Mars. Sensitivity trade study to allow for longer ranges, larger payloads, or longer hover times.
- **Airspeed Sensing**: Investigate the efficacy and options for lightweight airspeed sensing on Mars, critical for daily preflight safety assessments, and for in-flight wind estimation for improved controllability and forced-landing cases.
- **Science:** Three missions/science themes analyzed, and payloads selected for: 1) Becquerel Crater Mission: Mapping and Stratigraphy; Aeolian and slope processes, 2) Milankovic Crater Mission: Volatiles and climate; Atmospheric science; Geophysics and the subsurface, and 3) Palikir Crater Mission: Aeolian and slope processes; Mapping & stratigraphy; Geophysics and the subsurface; Atmospheric science.
- **Flight Software and Avionics:** Following in the footsteps of the M2020 MHTD, Mars Science Helicopter leverages F Prime, a software framework aimed at cube-sats and other small-scale spaceflight systems, and a Qualcomm Snapdragon System-on-Chip as its core compute unit. This avionics architecture will be the core foundation of MSH autonomy for FY20 and FY21.
- **Field Tests Campaign:** The final field test campaign for MSH in FY19 took place in the Arroyo, east of JPL. It was a joint test campaign comprised of both the Mars Science Helicopter System task and the sister-task, Advanced Navigation for Future Mars Rotorcraft task.

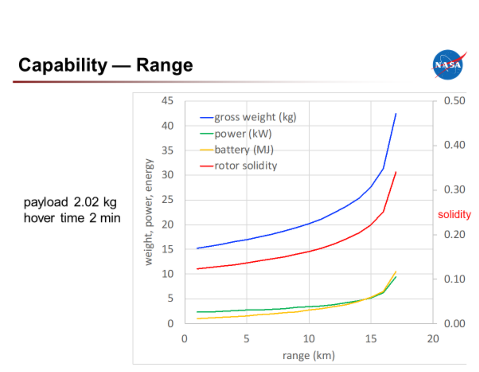
Benefits to NASA and JPL (or significance of results):

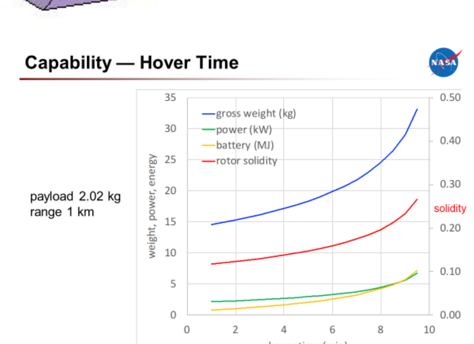
- The unprecedented mobility offered by a Mars helicopter allows scouting potential science sampling targets and traverse paths in advance of a surface rover and provides improved context for local and regional geologic interpretations. A helicopter on Mars would extend the scope of possible science far beyond the range of a traditional lander or rover. Data could be gathered for extreme terrains a rover could not traverse, allowing for investigation of high-priority science targets such as Recurring Slope Lineae (RSL) and active gullies. Visible imaging from a helicopter would bridge the resolution gap between orbital images and landed investigations.
- By providing a new platform for regional high-resolution sensing and extreme terrain access, Mars helicopters enable new mission concepts responsive to the 6x strategic themes of life (e.g., access to RSL), geology (access to diverse sites and extreme terrains), climate (direct observation of low-altitude wind fields), and preparing for human exploration (demonstrating helicopter scouting concepts).
- **FY19 saw the crucial first step towards sending a rotorcraft capable of autonomous science investigation, exploration, and discovery to Mars. In partnership with NASA ARC, we have designed a new Martian rotorcraft capable of delivering airborne payloads across the vast reaches of Mars and explore areas never before accessible to humanity. Over the next two years we will integrate our first science payloads to our earthbound-demonstrator, develop the technologies and autonomy needed to deploy these payloads on Mars, and integrate cutting edge navigation algorithms from our sister-task, Adv. Nav. for Future Mars Rotorcraft.**



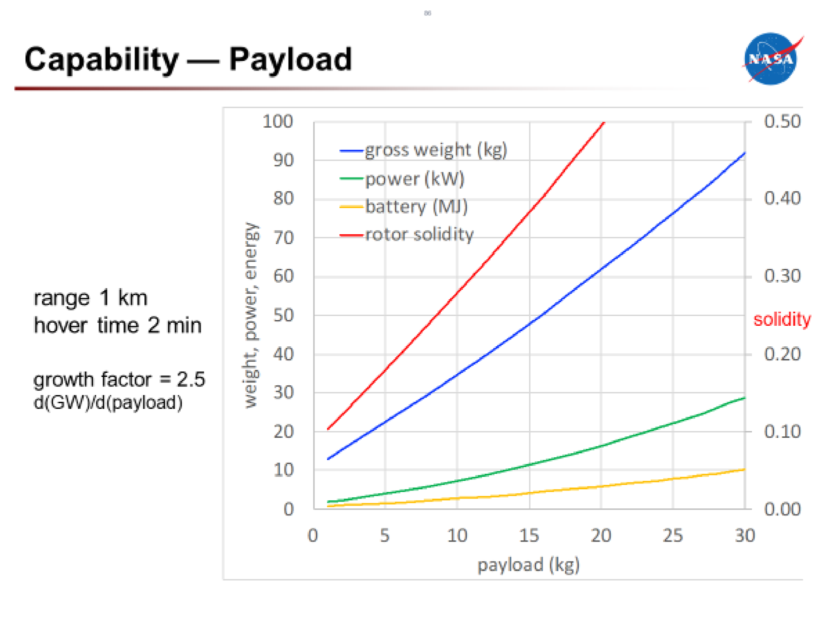


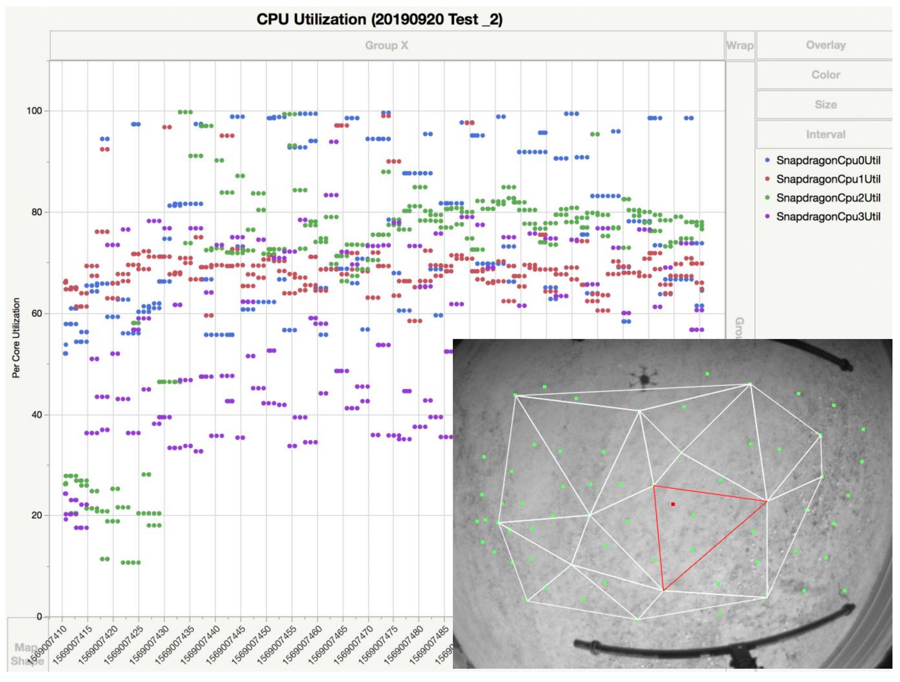


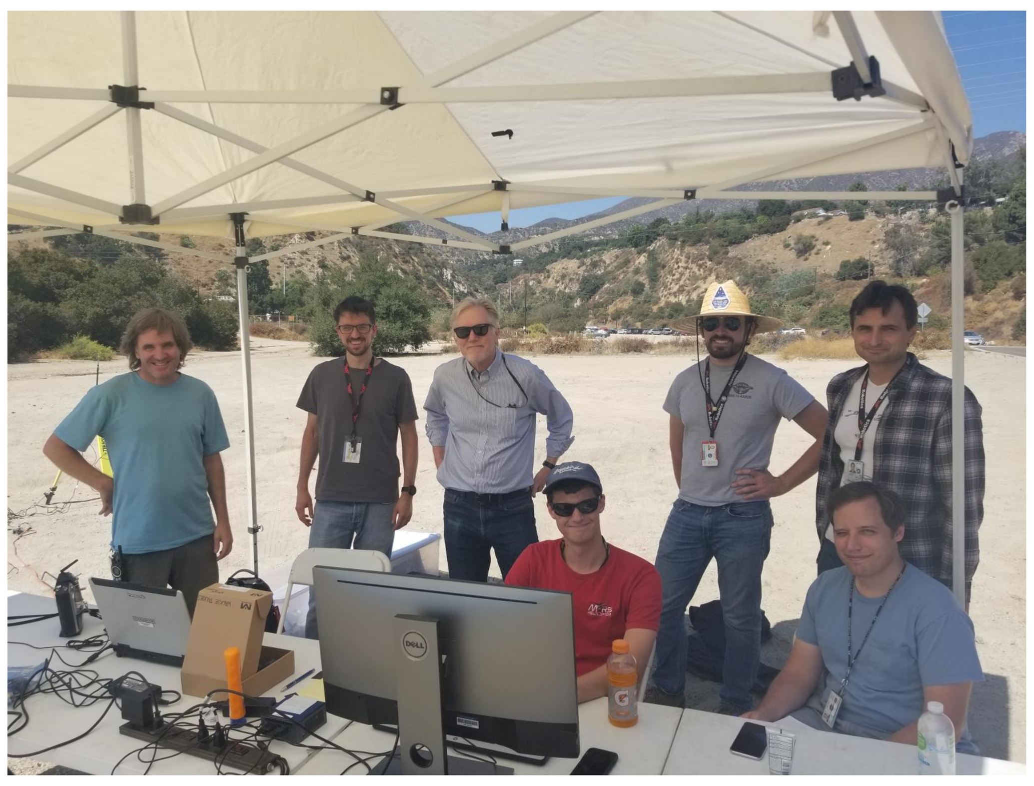


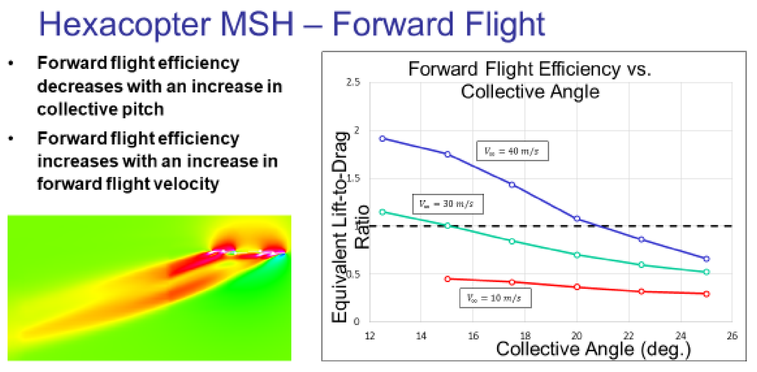


Desired Observation/ Measurement	Generic Instrument	Mass (g)	Power (W)	Heritage Example
Context Imaging	Visible Imager	<10		2020 Rover Navcam 2020 Hellicopter RTE
	Multispectral Imager (VNIR)	>300	4-8	COTS: Tetracam & RedEdge
Fine-scale imaging	Visible Imager	>500		MSL MAHLI
Mineralogy	VNIR point spectrometer	500	10 (max)	PUFFER ISRU Mineral Mapper
	TIR point spectrometer	2400	5.6	Mini-TES
	Hyperspectral VNIR spectrometer	>500	13 (max)	Headwall Nano-Hyperspec
	Mossbauer	200		MER MB
Elemental chemistry	APXS	240		MSL APXS
	XRF			PUFFER (V. Scott)
Atmospheric pressure, temperature, winds, and humidity	Meteorology package	1200-5500	5-17	MSL REMS 2020 MEDA
Surface temperature/ thermophysics	TIR imager	100	2-4	COTS FLIR
Dust particle size distribution	Nephelometer	300		
Atmospheric species (water vapor, CO2, methane)	Mini Tunable spectrometer	300	0.25	Mini TLS (L. Christensen) MSL TLS
	Sensor on a chip / "Chemical nose"	<100	7.6 (max)	PUFFER HOLMS
Subsurface ice/regolith moisture	Neutron Spectrometer	300-500	5	MSL DAN
Regolith mechanical properties and conductivity	Compact mechanical or thermal probe / penetrometer	150	<1	SPARTA PHX TECP
Interior structure and properties, subsurface layering	Ground penetrating radar/sounder	3000	5-10	2020 RIMFAX
	Thumper & geophone			
	SAR	~1,000		
Surface topography, altitude	LIDAR			
	Stereo imaging, DEM	<10		2020 Helicopter RTE
Magnetic field	Magnetometer	100		Psyche









National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

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Publications:

- J. Delaune, R. Brockers, D. Bayard, H. Dor, R. Hewitt, J. Sawoniewicz, G. Kubiak, L. Matthies, T. Tzanetos, J. (Bob) Balaram: Extended Navigation Capabilities for a Future Mars Science Helicopter Concept. Abstract accepted to IEEE Aerospace 2020.
- J. Balaram, I. J. Daubar, J. Bapst, T. Tzanetos, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA : HELICOPTERS ON MARS: COMPELLING SCIENCE OF EXTREME TERRAINS ENABLED BY AN AERIAL PLATFORM. Ninth International Conference on Mars 2019 (LPI Contrib. No. 2089)

PI/Task Mgr. Contact Information:

Teddy Tzanetos 626-319-1971 Tzanetos@jpl.nasa.gov

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