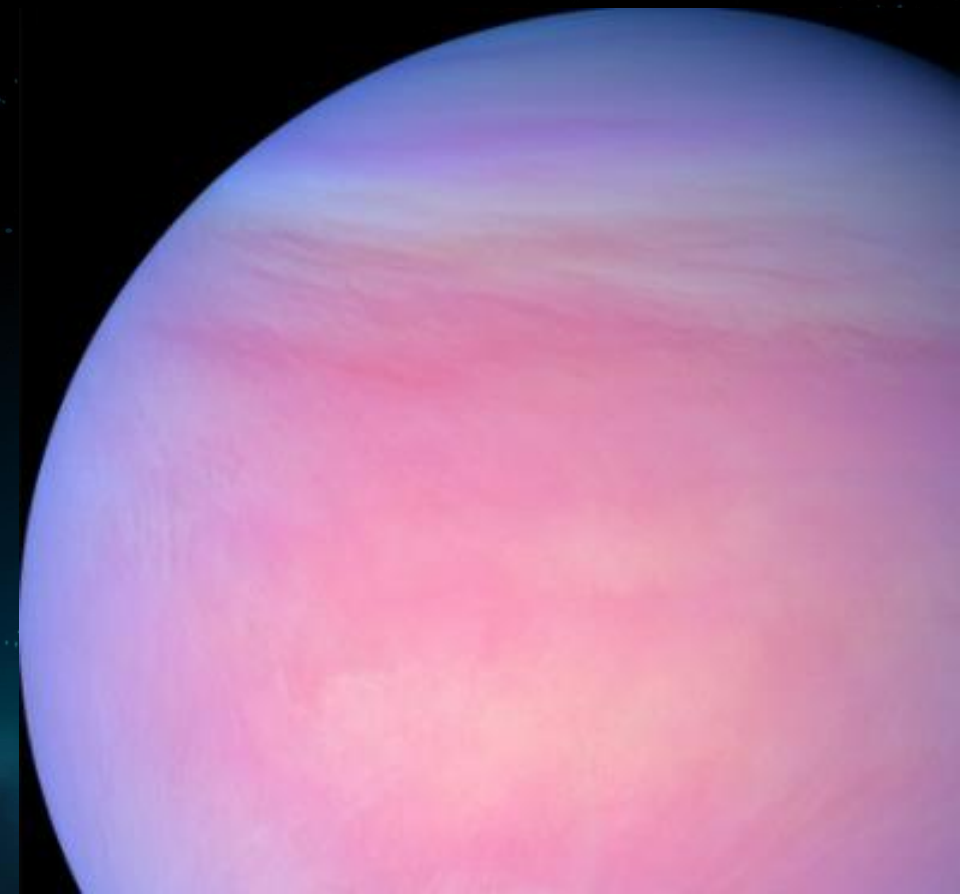




Potential Science Enabled by a Long-Duration Venus Lander

T. Kremic (NASA Glenn Research Center) and
R. R. Herrick (University of Alaska Fairbanks)



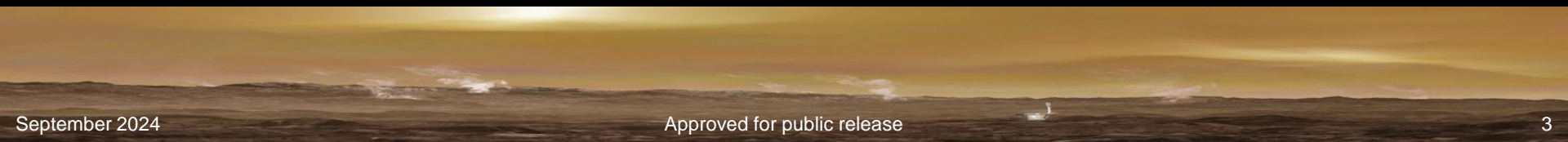
Outline

- Why Insitu Surface Science?
- Potential Science Enabled by a Long-Duration Lander
- Desired Lander Capabilities
- Summary of Current Status



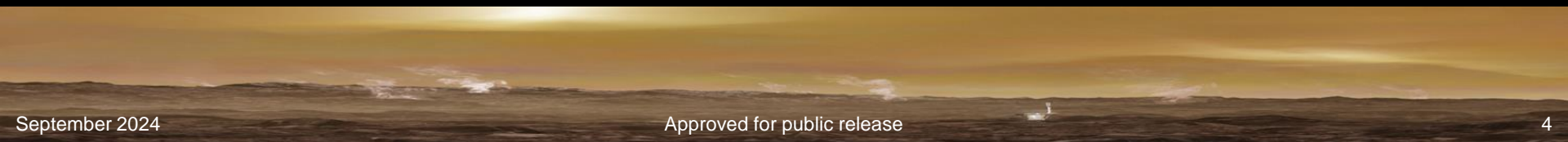
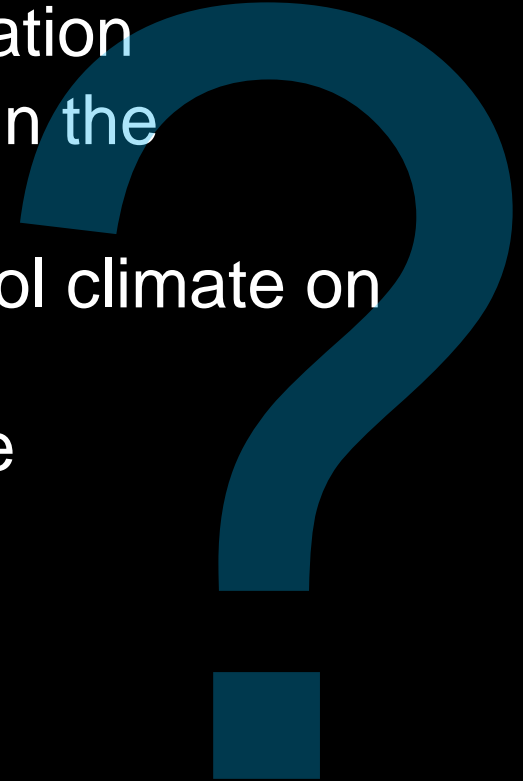
Motivation

- No need to convince this audience Why Venus is an important science target
- Why Insitu surface measurements?
 - Insitu measurements from the surface are critical for:
 - Understanding surface composition
 - Constraining geologic history
 - Determining rate and nature of seismic activity
 - Constraining the interior structure and composition
 - Understanding the physical and chemical processes that shape the surface
 - Determining if Venus hosted an ocean in the past



Motivation continued

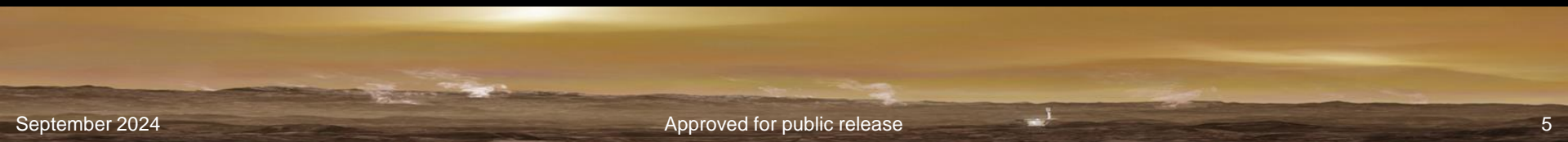
- Insitu measurements from the surface are critical for:
 - Determining dynamics in the deep atmosphere and how that may contribute to super rotation
 - Understanding transport of volatiles in the atmosphere
 - Understanding processes that control climate on Earth-like planets
 - Determining thermal energy balance



Potential Science Enabled

Atmosphere

- Extended operations at Venus could provide insights in the composition and variability of the deep atmosphere
 - Better constrain constituents in deep atmosphere
 - Help constrain potential sources and variability of SO₂ in upper atmosphere
 - Potentially capture outgassing events gaining insight into interior volatile abundance / makeup and chemical reaction rates in the atmosphere
- Capture wind speeds and direction, temperature and pressure data over time will help :
 - Understand the climate/weather on Venus and how that may be changing
 - Provide insight into atmospheric dynamics and what role the deep atmosphere may have in super rotation
 - Identify potential chemical transport processes
 - Estimate the momentum exchange between the atmosphere and solid body
 - Determine if the deep atmosphere is in thermodynamic equilibrium

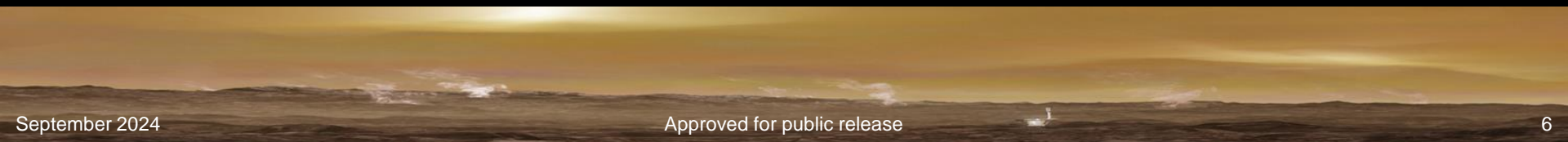


Potential Science Enabled

Surface

Extended operations on the surface
Venus could:

- Enable measurements of key reactions between the atmosphere and surface
 - Potentially constraining key elemental constituents
 - Constraining reaction rates with the surface
 - Determining depth and physical / chemical characteristics of the surface rind layer
 - Insight into surface age and geologic history
- Provide insight into processes that have shaped and are shaping the surface
- Determine solar energy deposition and energy transfer at the surface

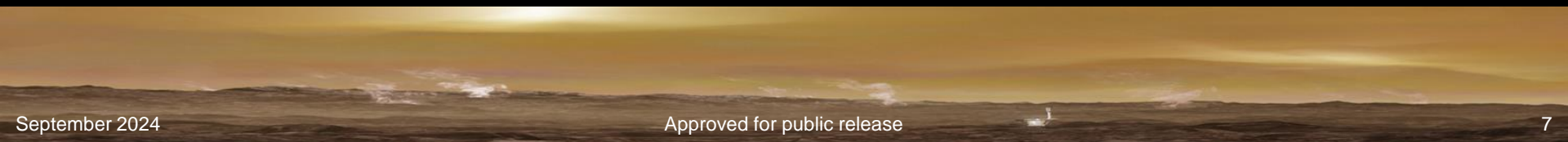
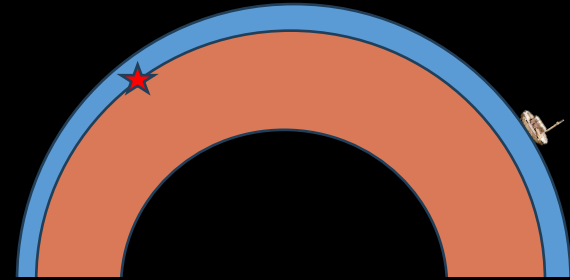


Potential Science Enabled

Interior

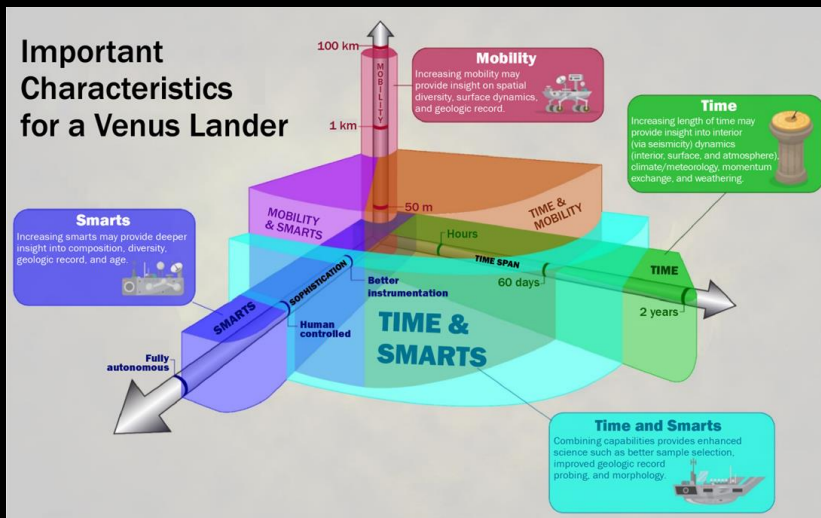
Operations at the Venus surface would provide:

- Insights in the composition and structure of the interior
 - Frequency of dynamic events
 - Nature of geophysical events
 - Bulk composition and interfaces
 - Water budget
- An additional example for comparative planetology of terrestrial bodies
- Help constrain moment of inertia / interior mass distribution
- Determine presence of weak or remnant magnetic field



Desired Lander Characteristics

- The recent surface platform study¹ explored what lander characteristics would be most impactful to a variety of science questions
 - Operating time is identified as a key characteristic



“H” indicates highly impactful to the desired capability, “S” is somewhat impactful

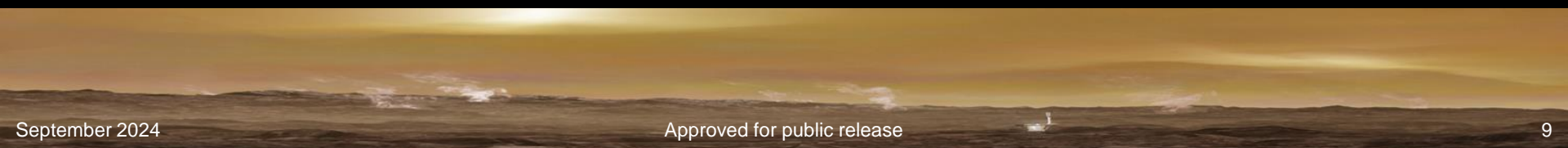
Science field	Capability			
	Time	Smarts	Mobility	MSM
Interior				
Structure	H			H
Composition	H	S		H
Dynamics	H			H
Heat flux	S			S
Surface				
Composition		S		S
Dynamics (eruptions, flows, ...)	H	S	H	
Diversity (spatial)	H	S	H	S
Morphology	H	H	S	H
Stratigraphy	H	H	H	H
Surface-atmosphere interactions				
Gas and surface composition	H	H		H
Winds	H			H
Reactions	H	H		S
Momentum exchange	H		S	H

Desired Lander Characteristics

- The key technologies that will provide the desired characteristics are shown in the table below

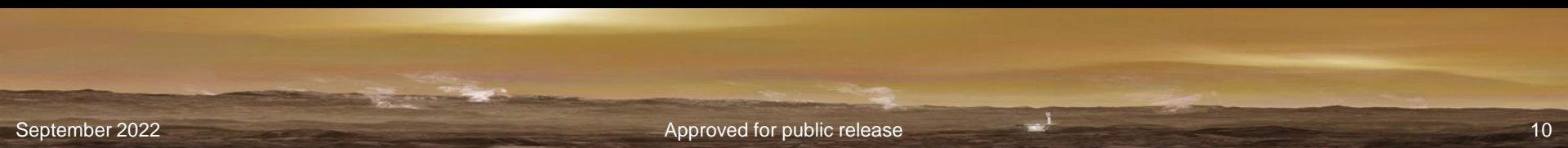
Critical underlying and supporting technology	Capability		
	Time	Smarts	Mobility
Power (low—10s of watts or less)	H	H	
Power (high—100s of watts)			H
Cooling (will also need power (high))	S	H	S
High-temperature electronics/memory/power processing	H	H	H
Mechanisms (drills, wheels, ...)			H
Autonomous operations and navigation		H	H
State-of-art instruments		H	

“H” indicates highly impactful to the desired capability, “S” is somewhat impactful



Top Level Status

- NASA has invested in technology development efforts to achieve the desired capabilities
 - This has occurred through projects such as LLISSE (Long-Lived Insitu Solar System Explorer), the HOTTECH program and other funded efforts.
- In particular LLISSE as made tremendous progress on the capability to enable operations of a lander on the Venus surface. Develops that occurred included
 - Robust high-temperature electronics that operate at 500C or higher
 - High-temperature batteries
 - Communication system
 - Antenna, transmitter, supporting circuitry and components
 - High-temperature instruments & sensors
 - Enabling measurement of seismic temperature, pressure, wind, chemical abundance of atmospheric species,
- The HOTTECH program has been developing high-temperature non-volatile memory, solar cells, motors, seismometer, UV sensor, imager, and more
- Many components and several subsystems have matured to a technology readiness level (TRL) of 4-5, TRL-6 being the level needed to be proposed on a NASA mission



A vibrant space-themed background featuring a curved view of Earth at the bottom, a bright sun or star in the lower left, and various celestial bodies including a ringed planet, a reddish planet, and a large blue planet. The background is filled with stars and nebulae in shades of blue and green.

Venus In Situ Exploration – Surface

60 day survival in extreme environments

HOTTech-2 funded grants:

- Advanced Co-Based Nanocrystalline Soft Magnetics for Extreme Temperature Inductor Applications/Paul Ohodnicki, University of Pittsburgh
- Venus Surface Solar Array/Joel Schwartz, Jet Propulsion Laboratory
- A High Temperature Transmitter for Venus Surface Environment/Laurence Sadwick, Innosys, Inc.
- Non-Volatile, Low Power, and High Density SiC Memory For Future Venus Missions/Phil Neudeck, NASA Glenn Research Center
- High-Temperature MEMS based Venus seismometer/Tibor Kremic, NASA Glenn Research Center
- A Venus Durable Actuator and Electronics System/Erik Mumm, Honeybee Robotics, Ltd.
- High Temperature UV near field Imager/Emad Andarawis, General Electric Company

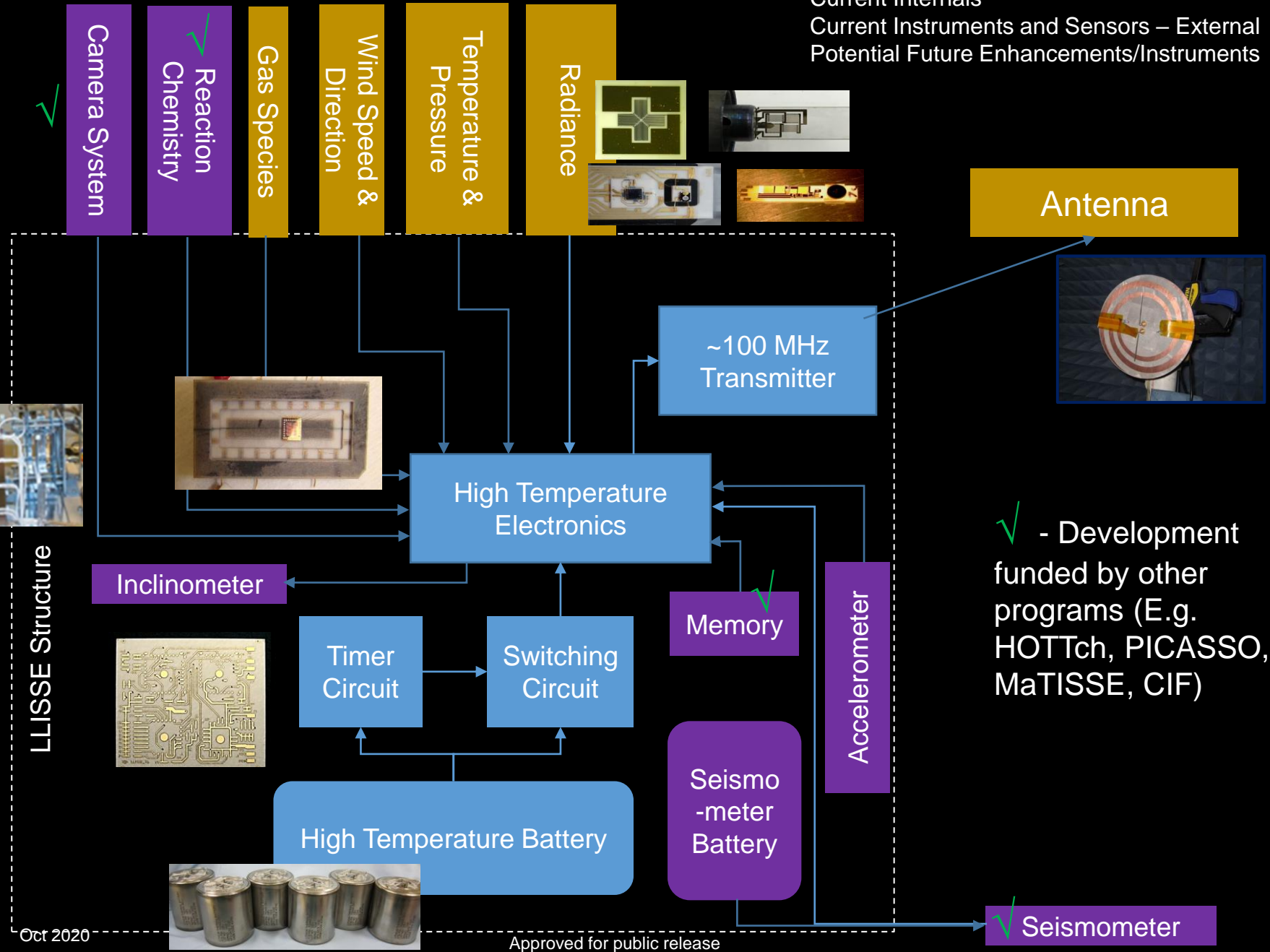
- **All tasks will demonstrate 60 day operation in GEER as part of the workplan**

- **A Community of Practice (CoP) was formed to encourage individual tasks to explore integration of individual technologies into more complex and capable subsystems**

LLISSE Block Diagram

Legend

- Current Internals
- Current Instruments and Sensors – External
- Potential Future Enhancements/Instruments



✓ - Development funded by other programs (E.g. HOTTch, PICASSO, MaTISSE, CIF)

Take-aways

- Long duration Venus landers would enable compelling new science, not achievable in other ways
- Needed lander characteristics have been studied, reported, and continue to be developed by various NASA projects and programs
 - E.g. LLISSE, HOTTech, and instrument programs
- Developments to date have notably matured lander subsystems and payloads. Hardware exists for subsystems and various levels of testing has been completed



LLISSE Concept



Full scale mock-up of LLISSE. Several components of the mock-up were already successfully tested in Venus surface conditions

Questions?

