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Section 9:
A-Prior Observations

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Agenda

- Capability Description, Benefits, Current State-of-the-Art
- Capability Requirements and Assumptions
- Maturity Level - Capabilities
- Maturity Level - Technologies
- Metrics
- Roadmap for Capability

Capability Breakdown Structure

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Human Planetary Landing Systems CRM # 7

A Priori Observations 9.0

9.1 Orbital reconnaissance requirements for surface site characterization.

9.2 Orbital reconnaissance requirements for atmospheric characterization

9.3 Robotic EDL measurements

A Priori Observations Capability Description

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9.1 Orbital Reconnaissance for Lunar and Mars site characterization

- Utilize existing and planned orbital and terrestrial-based surface observations to characterize and develop the surface site landing models & requirements for Lunar & Mars AEDL systems.

9.2 Orbital reconnaissance for Mars atmospheric characterization.

- Utilize existing and planned orbital and terrestrial-based Mars atmosphere observations to characterize and develop the atmosphere models & requirements for Mars AEDL systems. (Earth atmospheric characterization is not required for Lunar and Mars return)

9.3 Robotic EDL measurements

- Utilize existing and planned in-situ EDL reconstruction data to
  - Validate current and future atmosphere models
  - Validate vehicle aerodynamic & aeroheating modeling process
- Develop the in-situ measurement systems (a.k.a. EDL instrumentation) that acquire above reconstruction data.

Benefits

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Ultimately the benefits from this roadmap are ones of human safety and AEDL system design efficacy. Specifically:

9.1 Orbital Reconnaissance for Lunar and Mars site characterization

- For Lunar & Mars Landing: Acquisition of site images with <1 m resolution from orbit enables safe site selection and use of imagery for terrain-relative navigation for pin point landing.

9.2 Orbital reconnaissance for Mars atmospheric characterization.

- Characterization of the relevant variation of the Mars atmosphere (over multi-year timescales) will enable the design of a safe Human Scale AEDL system.
  - We do not know if we are under-designing or over-designing our AEDL systems.

9.3 Robotic EDL measurements

- In-situ measurements taken during EDL (and after) will validate the models that are created based on long term atmosphere observations.
- In-situ measurements taken during EDL will validate the processes used to construct AEDL system aero-database and aeroheating models that are created based on long term observations.

9.1 Orbital Reconnaissance for Lunar and Mars site characterization

- Lunar state of the art:
  - 100 - 200 m resolution, global coverage (Clementine).
- Mars state of the art:
  - 100 - 200 m resolution (Viking, MGS, Odyssey, Mar Express)
  - global coverage, small % with 3 m coverage
  - 100 m global topographic elevation data.

9.2 Orbital reconnaissance for Mars atmospheric characterization.

- 2-3 km vertical resolution thermal (density) profiles at 100 km centers at 2 pm local solar time (MGS TES)
- Minimal data on vertical dust distribution and its diurnal, seasonal and long term variability.
- Minimal wind data in 2 - 70 km range (some reconstructed data from 5 landings), however unvalidated Mesoscale wind models exist at 2 sites.

9.3 Robotic EDL measurements

- Partial aero-reconstruction performed for Viking,MPF & MER based on IMU data.
- Aerothermal (TPS) reconstruction performed for Viking and some for MPF.
- No external pressure data.

Assumptions

- Lunar reconnaissance orbiter before 2014
- Mars reconnaissance orbiter before 2009
  - Acquires 0.3 m resolution imagery of key landing sites.
    - Assume that the first human scale landings on Mars will be at locations that have been well characterized by MRO.
  - 2-3 km vertical resolution thermal (density) atmosphere profiles at 100 km centers.
- Future Mars orbiter mission(s) between 2013-2020 will have characterized the long term variability of the Mars atmosphere to enable detailed design of Human Scale AEDL system.
  - Better than 0.1 km resolution vertical thermal (density) atmosphere profiles at 10 km centers - all times of day.
  - Dust transport measurements between 2 - 100 km.
  - Better than 0.1 km resolution vertical wind profiles at 2 km centers.
- Future Mars landers will be instrumented to measure atmosphere pressure, temp, dynamic pressure, aeroheating.

Technology Maturity Level

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9.1 Orbital Reconnaissance for Lunar and Mars site characterization

- Sub meter optical resolution technology is at TRL 6, just need to do it.
- Global assessment at submeter resolution is difficult due to large data volumes - > could take many years at today's communication capabilities.

9.2 Orbital reconnaissance for Mars atmospheric characterization.

- For sub km density, thermal technology is at TRL 4-5.
- For sub km dust profiling, technology is at TRL 1-2.
- For sub km wind profiling, technology is at TRL 1-2.

9.3 Robotic EDL measurements

- Aerothermal measurement technology is at TRL4-6
- Aerodynamic (IMU) measurement technology is at TRL 6
- Pressure / wind measurement technology is at TRL 2-4

Technology Gaps

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9.1 Orbital Reconnaissance for Lunar and Mars site characterization

- If global high resolution optical imagery is required for site selection (not obvious that it is), then higher data volume orbiter data delivery systems are required.

9.2 Orbital reconnaissance for Mars atmospheric characterization.

- Need to develop Doppler (LIDAR-like) limb sounding of dust for dust distribution and large scale wind.
- Other than “spotty” multiple landers (equivalent terrestrial weather balloon measurements), there are few options for higher resolution wind and density measurements.

9.3 Robotic EDL measurements

- Need to develop small pressure/temp transducers for aerosurfaces (thermal & mass challenge).
- Need high rate IMU (inertial measurement) data.

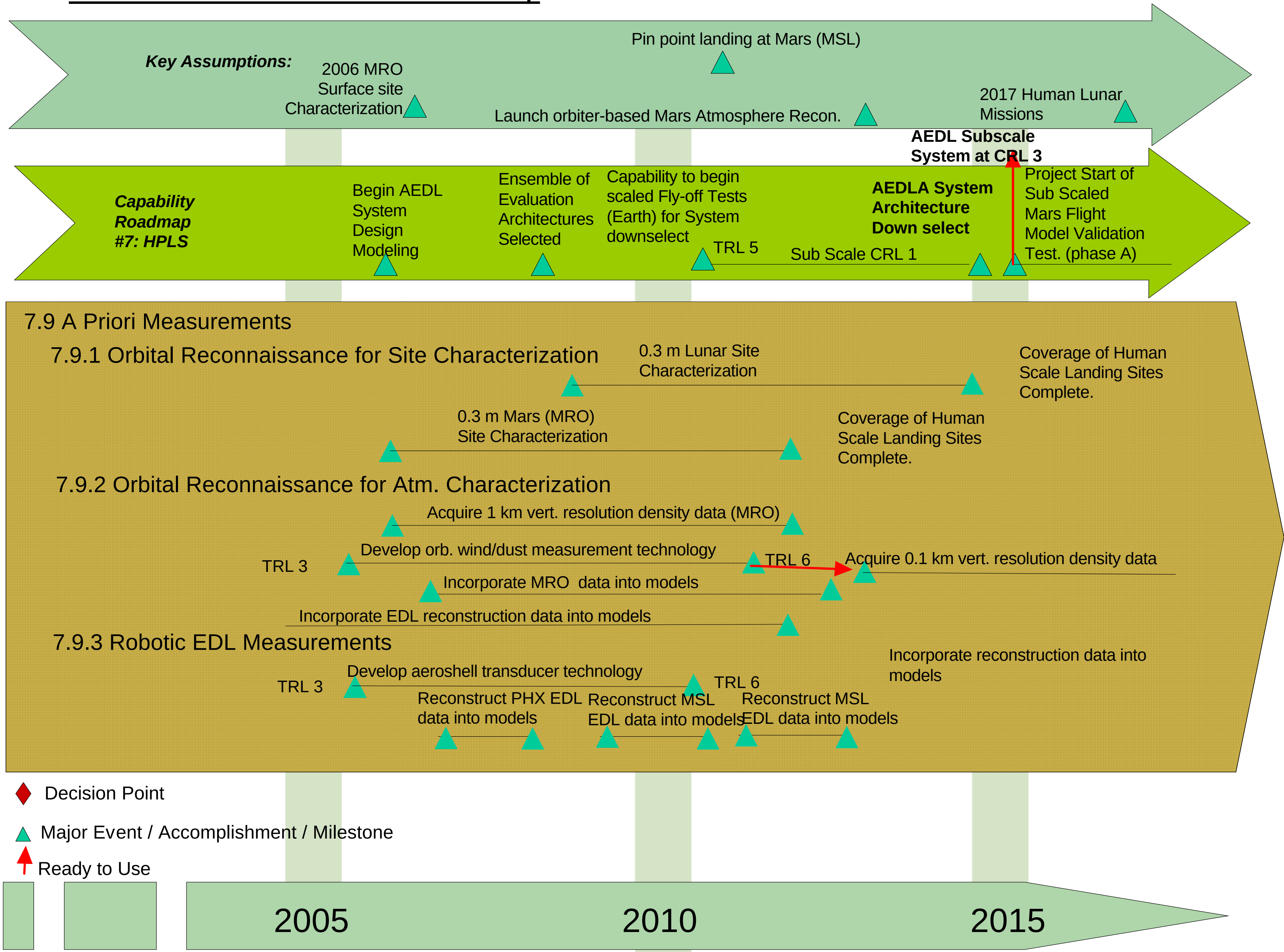
Metrics

9.1 Orbital Reconnaissance for Lunar and Mars site characterization
- Percent coverage at sub-meter spatial resolution.

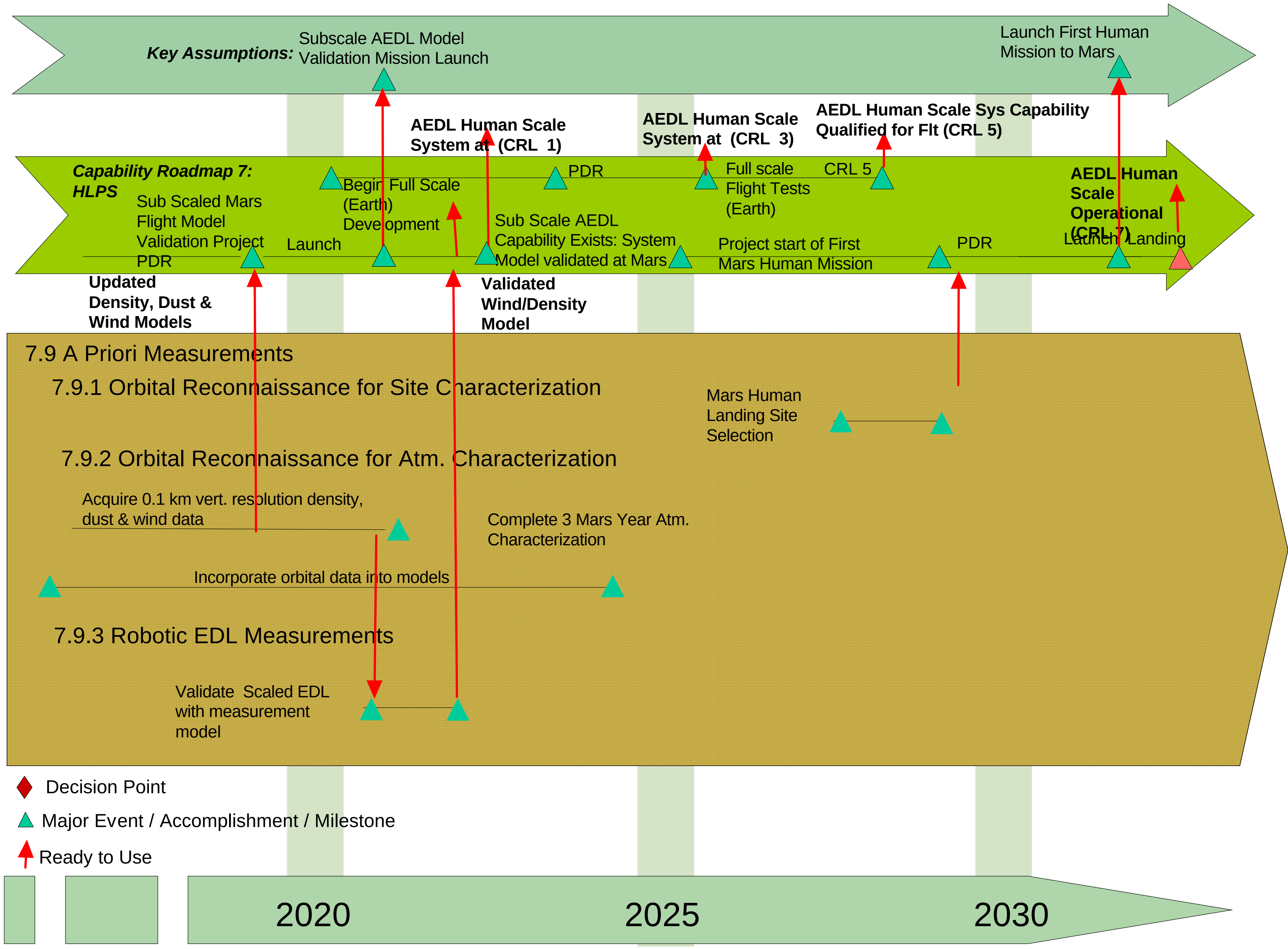
9.2 Orbital reconnaissance for Mars atmospheric characterization.
- The extent that high resolution (sub km) global "mesosphere" atmosphere models have been validated with actual measurements.

9.3 Robotic EDL measurements
- The extent that an EDL landing's reconstructed atmosphere validates the corresponding atmosphere as measured from orbit.
- The extent that the reconstructed EDL trajectories can be explained by the atmosphere and aerodynamic models.
- The extent that the reconstructed EDL aerothermal profiles can be explained by the atmosphere and EDL trajectories.

Team 7.9: A Priori Measurements Roadmap



Team 7.9: A Priori Measurements Roadmap



A Priori Observation Summary

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- In order to design high reliability Human Scale AEDL systems for Mars, the models of the Mars atmosphere we use today need to be validated with actual data.
  - Measurements of dust, dust storms and its affects on density needs to be understood (especially variance).
  - Measurements winds, wind shears in the range of 2-70 km needs to be gathered.
  - A multi-year global weather observer orbiter is needed.
- Measurements of actual AEDL performance must be made to validate the modeling methodologies used to design today's robotic EDL systems so that these same methodologies may be used to design the Human Scale AEDL systems for Mars.