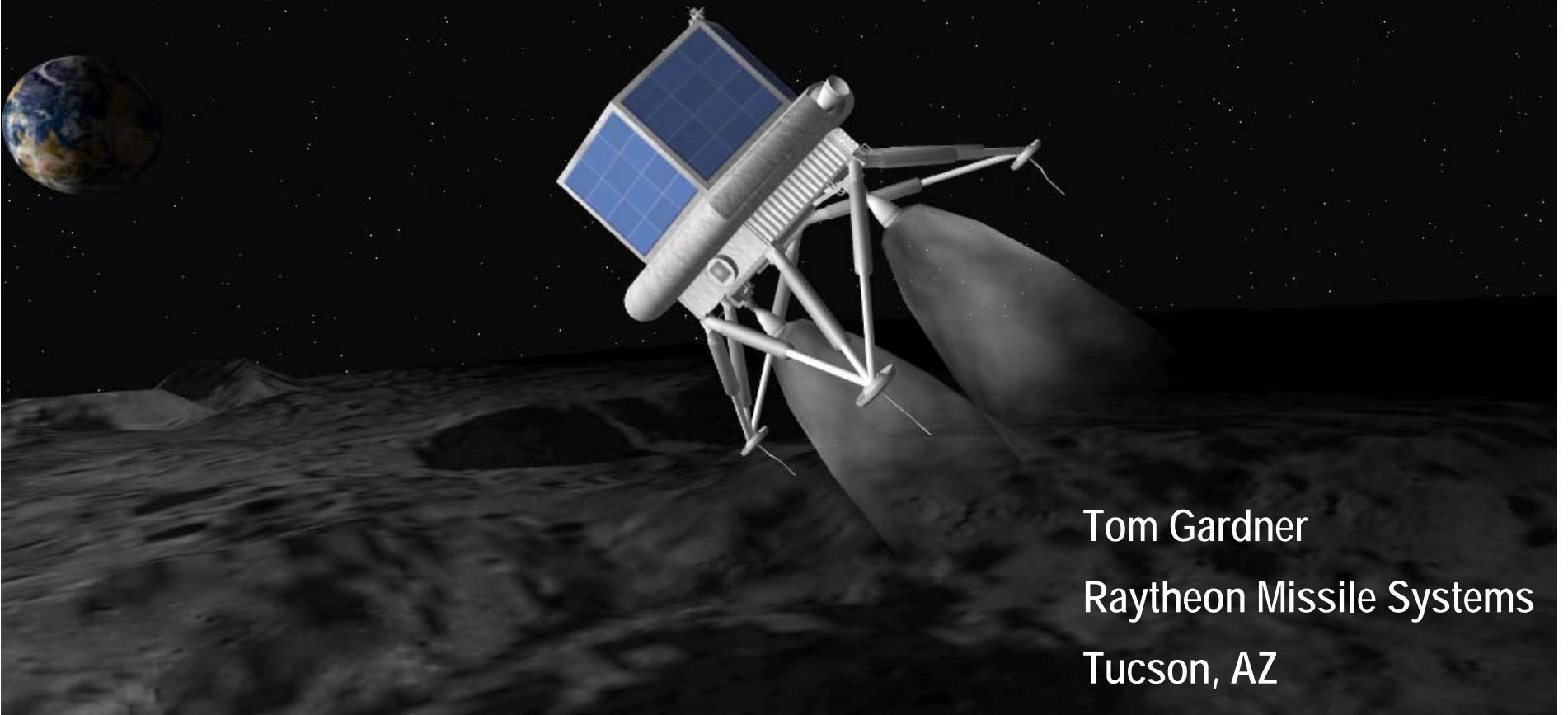


Raytheon

Customer Success Is Our Mission

Precision Landing: A Raytheon Perspective



Tom Gardner
Raytheon Missile Systems
Tucson, AZ


Raytheon Designed Precision GNC Systems



Exoatmospheric Kinetic Vehicle (EKV)

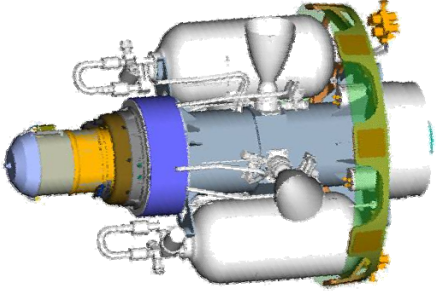


SM3 Kinetic Vehicle

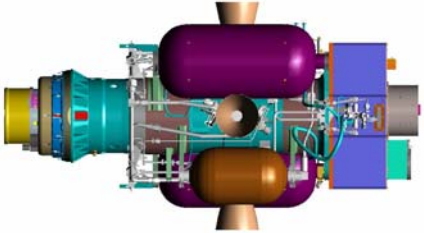


World Class Space Vehicle Production Facility

Kinetic Energy Interceptor (KEI)



NFIRE



Our Technology Focus

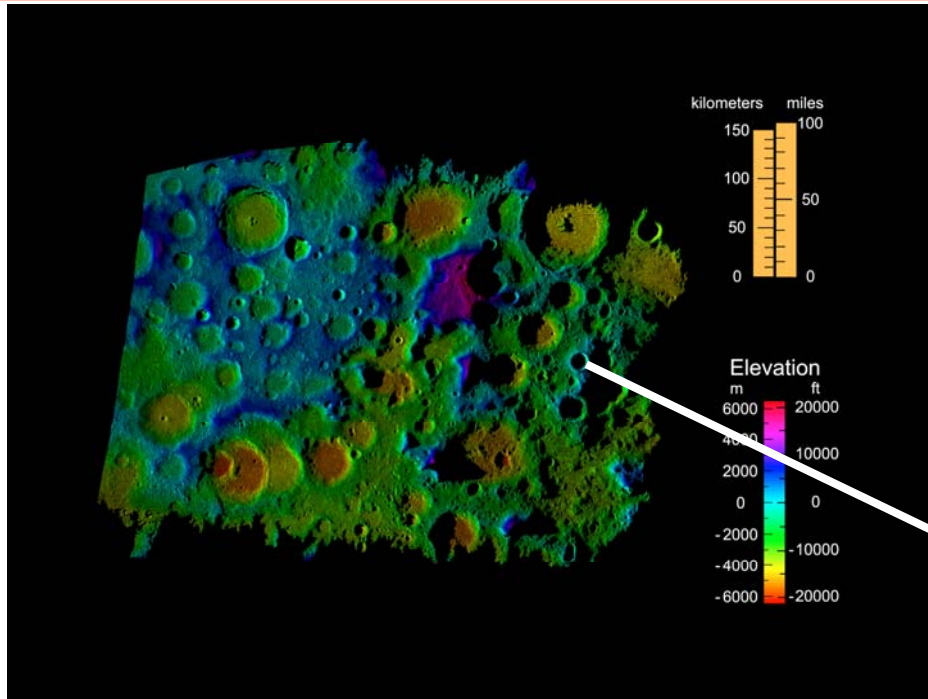


Precision Landing: Guidance, Navigation and Control

- **Raytheon's View of the Challenge**
 - Precision Landing as an Extension of Precision Engagement – The “Near Zero” Velocity Target Impact
 - Potential Human Interaction in the Real Time Process – Enabler or Source of Error?
 - Ideas are Not New But Implementation is Much More Accessible
 - System must also autonomously deliver cargo safely – Required for Overall Mission and Enterprise Success
- **Environment Drives the Potential Solutions**
 - Sortie vs. the Established Outpost/Base
 - Runway vs. Helipad vs. Open Terrain
 - What are the REAL design environment impacts/constraints
 - Robotic surveillance, both on orbit and surface in situ, is essential
- **Design considerations**
 - Data fusion from multiple sensors as an enabler
 - Sensor or subsystem failure resiliency and response
 - Reliability vs. System Redundancy – Most Tactical systems are single shot devices with VERY high reliability
 - Lateral Targeting Control Authority
 - Necessary vs. Sufficient Conditional Enablers, aka Precision Landing as Hazard Avoidance
 - Upgradeable System Architectures

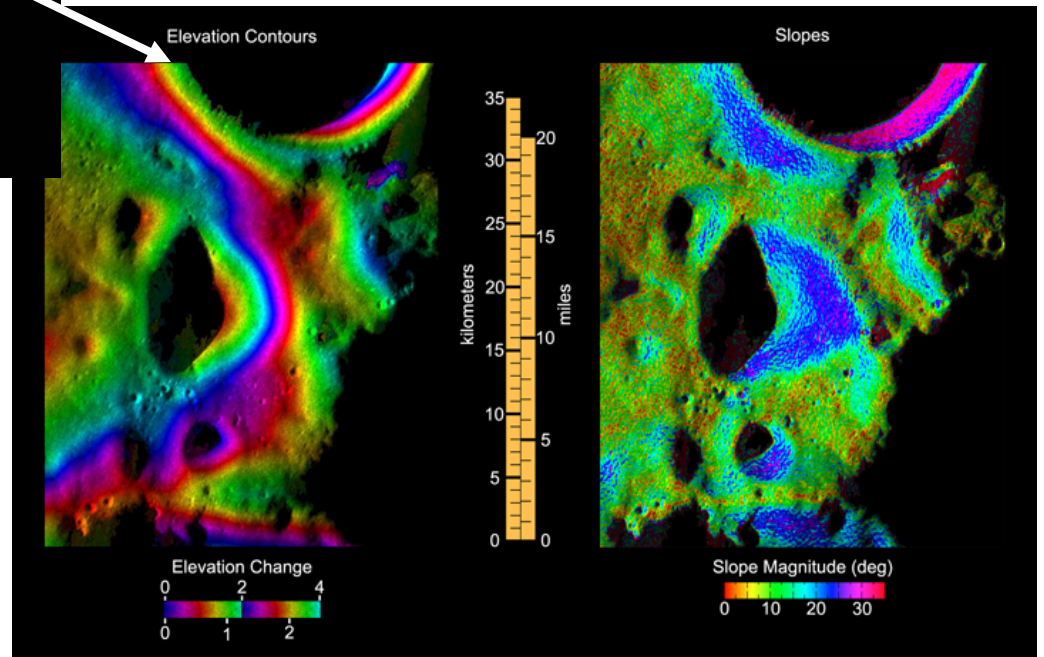
**Does 21st Century Technology for Precision GNC and
Other Space Systems Move the Pilot to the Passenger ?**

The Environment Challenge: Location, Location, Location



Elevation

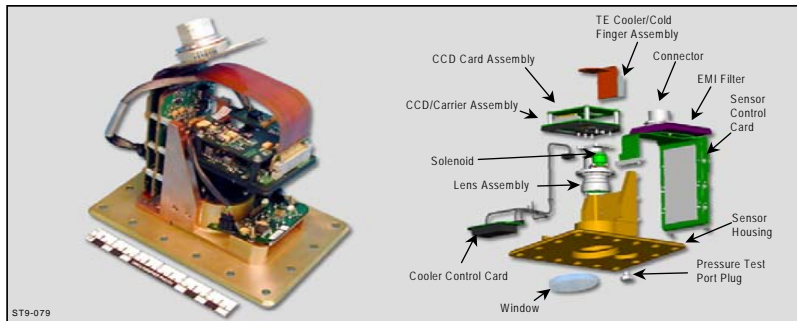
Elevation and Slope



Leveraging DSMAC for Planetary Precision Navigation

DSMAC Heritage

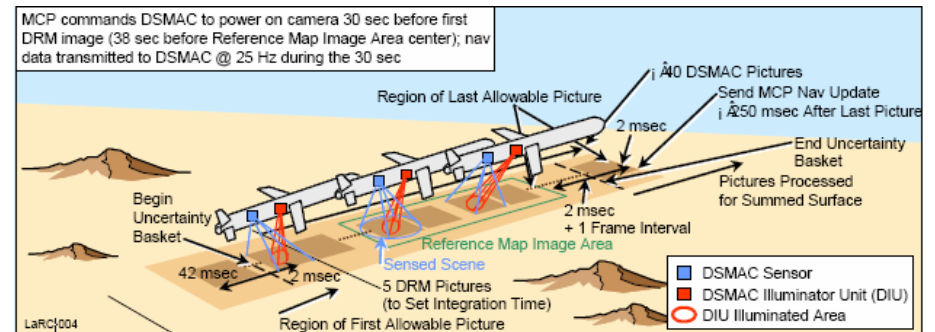
- Highly Accurate Navigation Aide since 1970s (Pre-GPS)
- Developed by the Naval Avionics Center (NAC) In 1978
 - Current version 3 by Raytheon (1998-present)
 - Modular, custom software correlation – very adaptable
 - Illuminator provides lighting for use during night flights



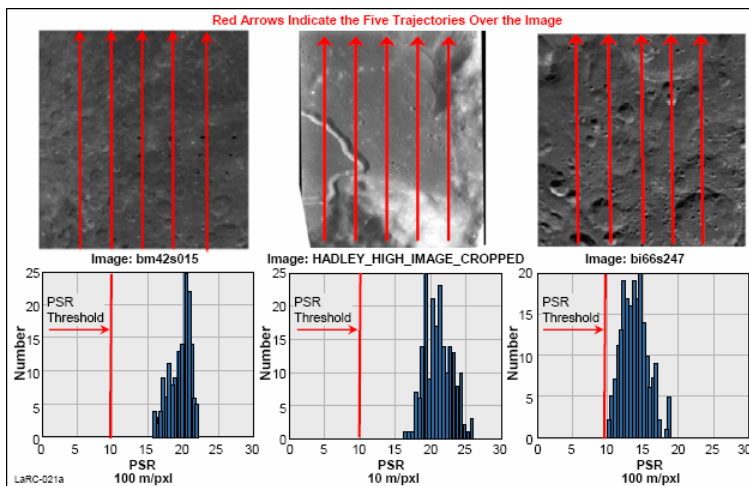
Operation

DSMAC provides accurate position update

- Reference map loaded onto missile before launch
- Images taken over the reference map area
- Position update supplied to autonomous GNC software from image with highest SNR

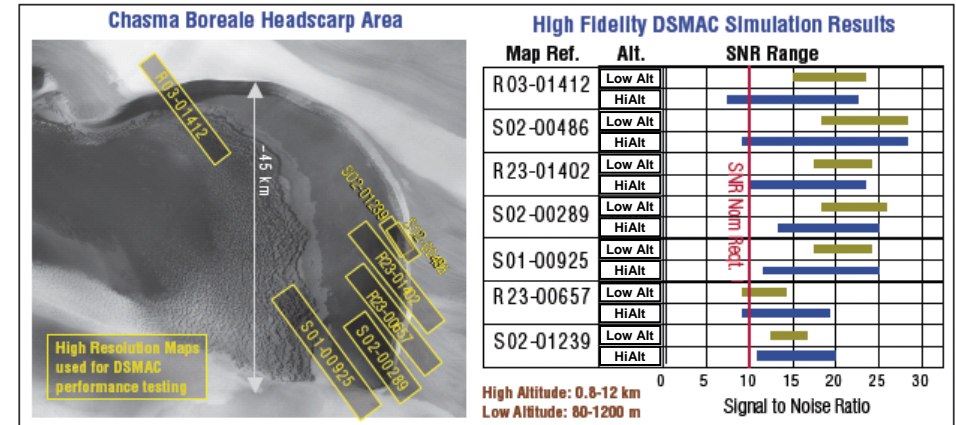


Lunar Application



- Excellent Correlation Confidence with Lunar Imagery
- Accuracy of position update dependant on reference map resolution

Martian Application



All tests in the Chasma Boreale Headscarp produced viable correlations.

Precision Terrain Aided Navigation (PTAN)

Next Gen DoD Navigation Aide: PTAN is a autonomous Navigation aide that measures terrain features, correlates those terrain features to stored Digital Terrain Elevation Data (DTED) and provides precision aircraft position equal to or better than GPS

- Sensor: Radar Altimeter Sensor
 - Replaces current Radar Altimeter



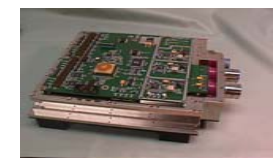
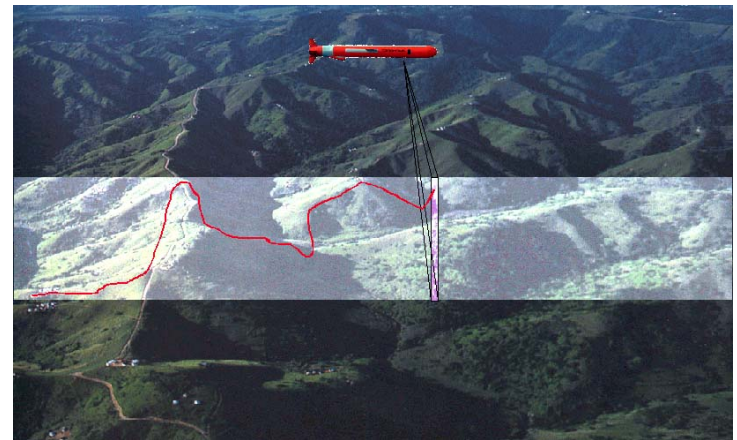
- Inertial Measurement Unit (IMU)
 - Provides short term vehicle velocity and attitude for phase computation



- Precision Digital Terrain Elevation Reference maps and memory storage
 - New and existing DTED are used for reference



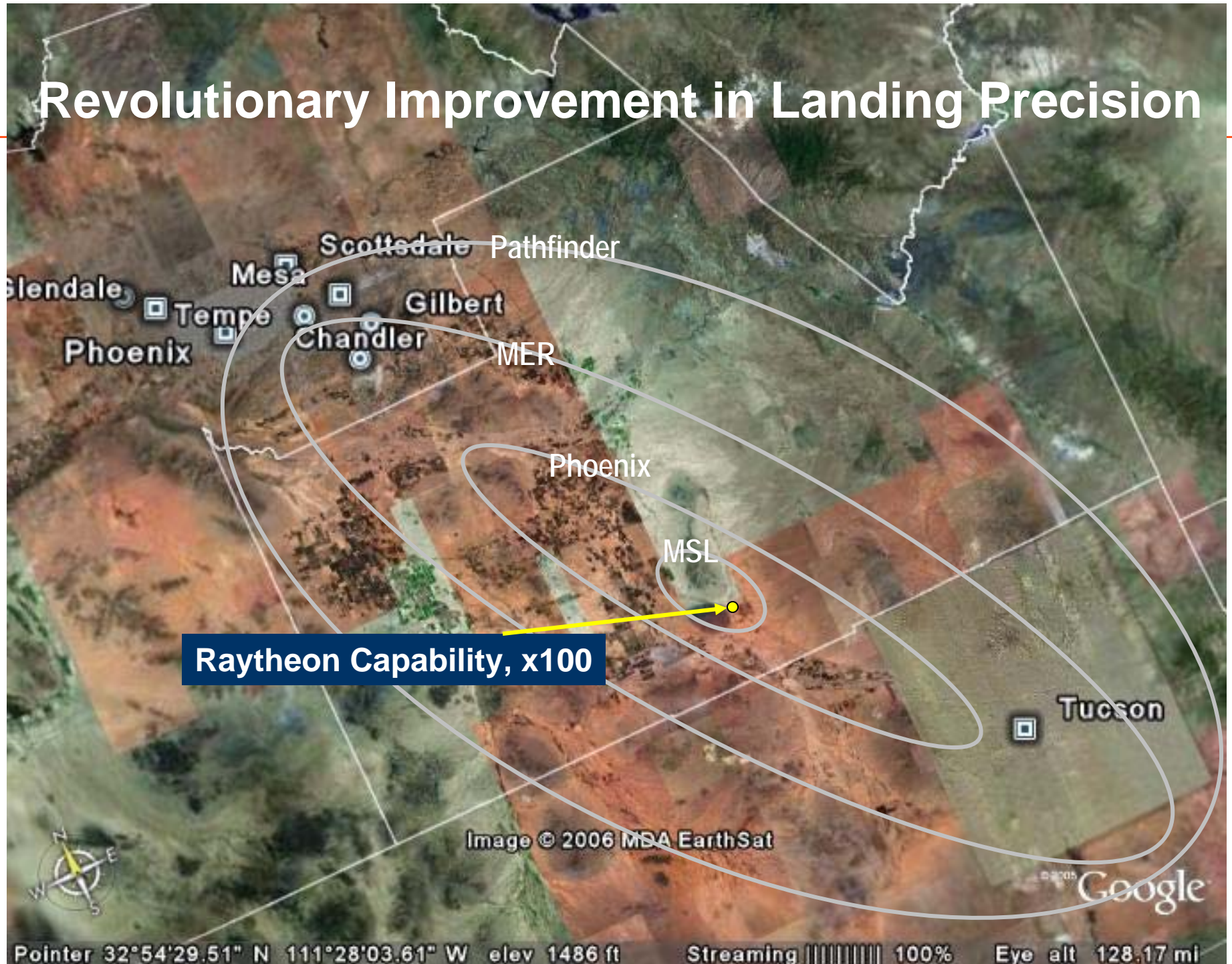
- Terrain Aided Navigation (TAN) Correlator Software
 - Correlates radar sensor elevation data to the digital elevation terrain map
 - Existing examples - TERCOM



PTAN cover off

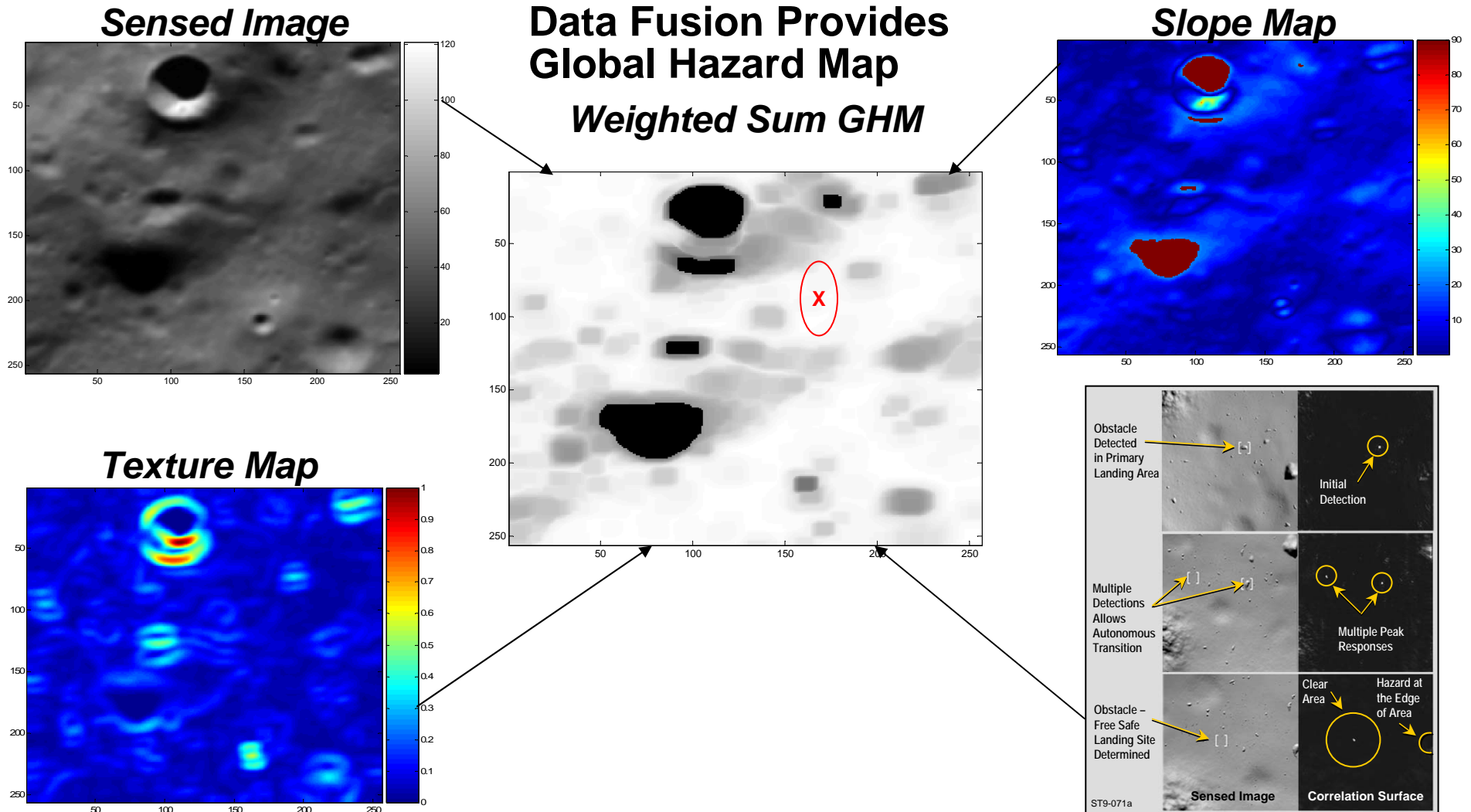
PTAN is Being Developed for UAVs, Aircraft and Tactical Tomahawk to Alleviate GPS Jamming

Revolutionary Improvement in Landing Precision



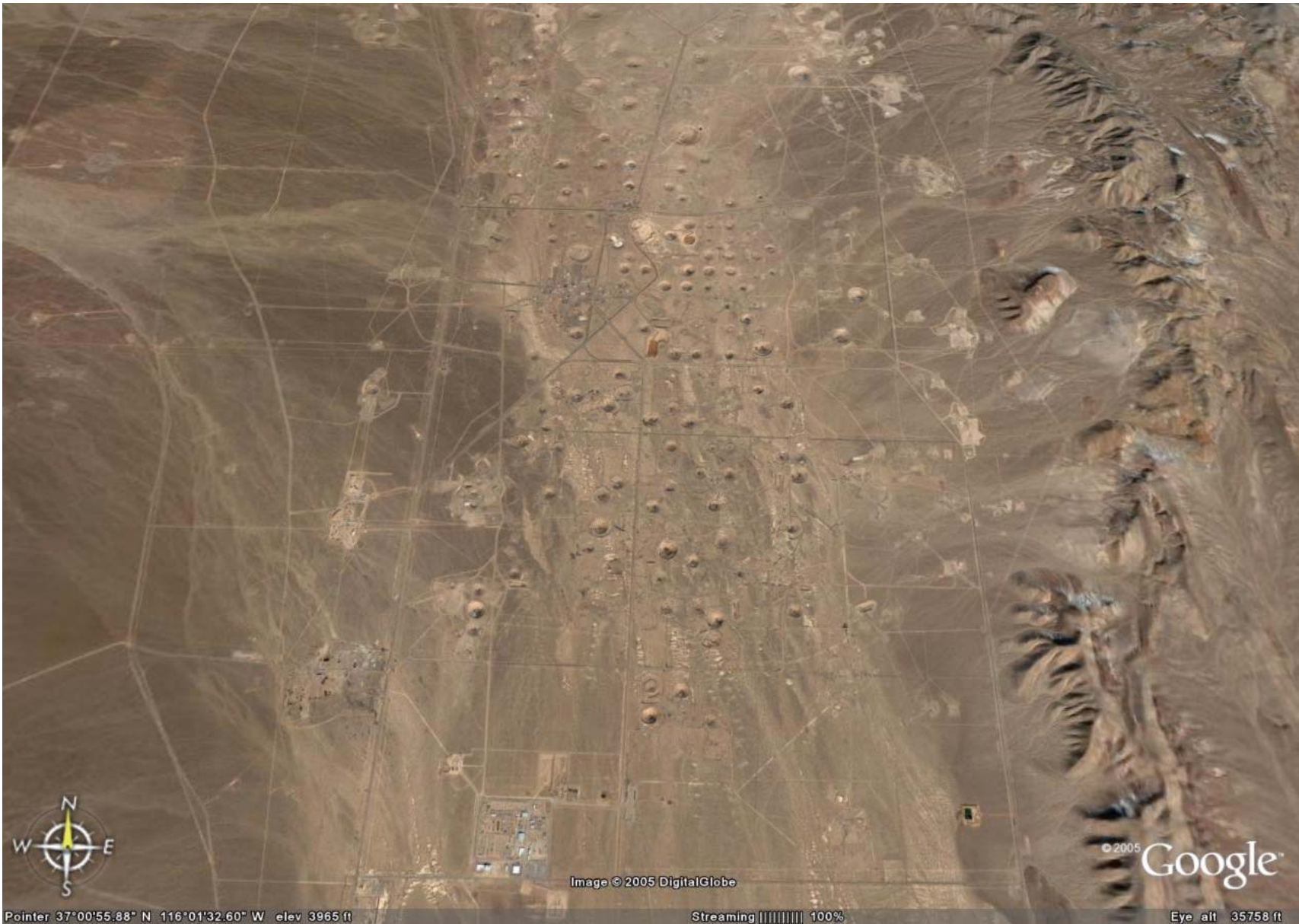
Raytheon Capability, x100

Hazard Detection Data Flow



Hazard Detection Process provides Safest Landing Position to Autonomous GNC Software

Considering NTS for Terrestrial Testing



X Prize: Tranquility Trek Returns to Apollo 11 (2009)

