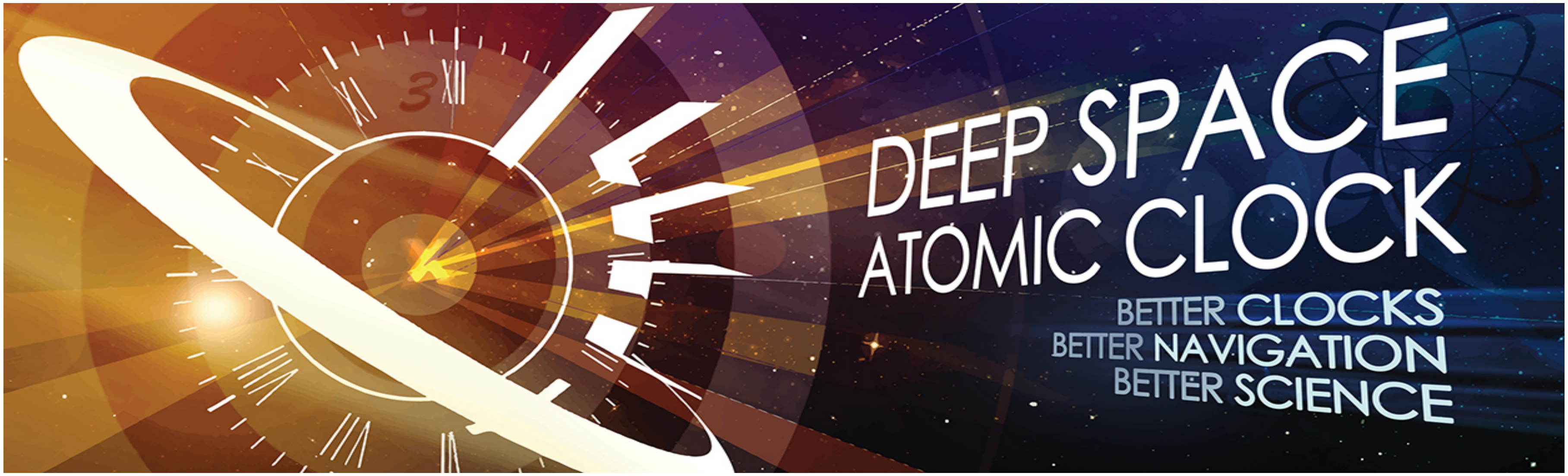
National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology



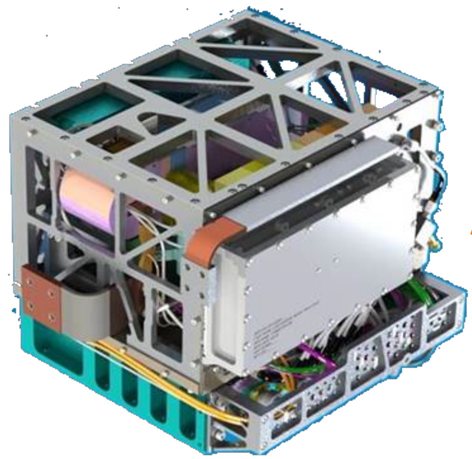
Discovery 2014 Briefing to Potential Proposers
Capabilities and Considerations for Incorporation Onto a Discovery-Class Mission

Allen H. Farrington
DSAC Project Manager
April 2014

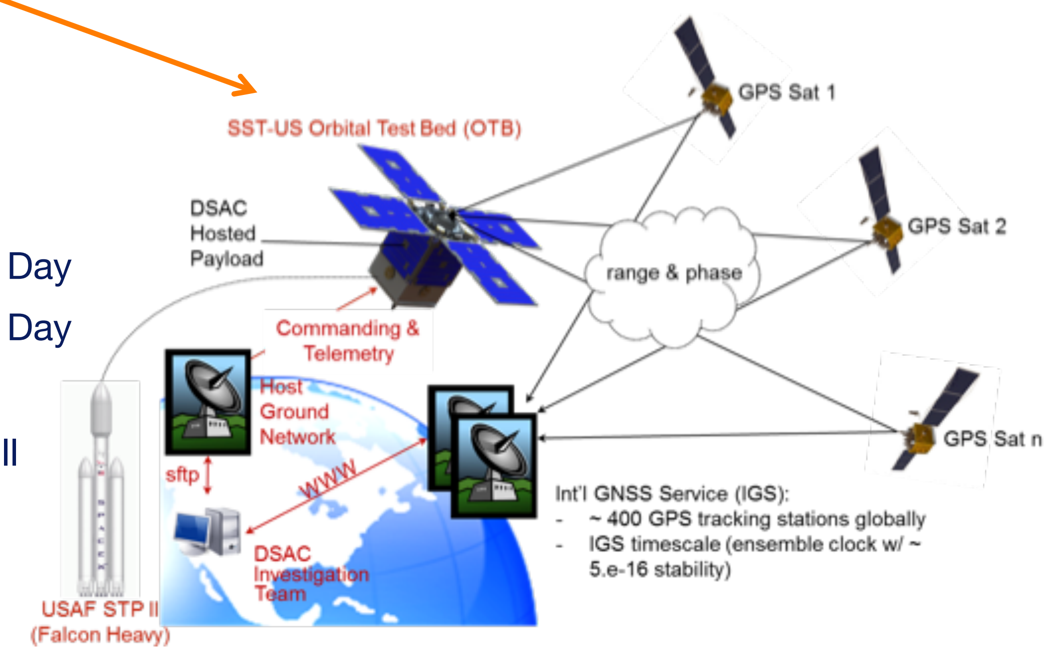
National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

Deep Space Atomic Clock Project

DSAC is a Flight Mission – Demonstrate Clock on Orbit (TRL7)



- Develop Advanced Prototype Clock for Year-Long Test Flight
- Demonstrate State of the Art Clock Stability (see below)
- Develop and Demonstrate Deep Space Navigation Tools and Usage of Clock in a One-Way Tracking Scenario



Requirements:

Clock prior to launch:	3.0 E-15 @ 1Day
On-orbit Clock Validation:	2.0 E-14 @ 1Day

Current CBE predicts that DSAC in-space will actually meet ground based performance (A.D. < 3.0 E-15 @ 1 day) which outperforms any existing space clock.

For More Information, Contact: Allen.H.Farrington@jpl.nasa.gov, Website: http://www.nasa.gov/mission_pages/tdm/clock/

National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

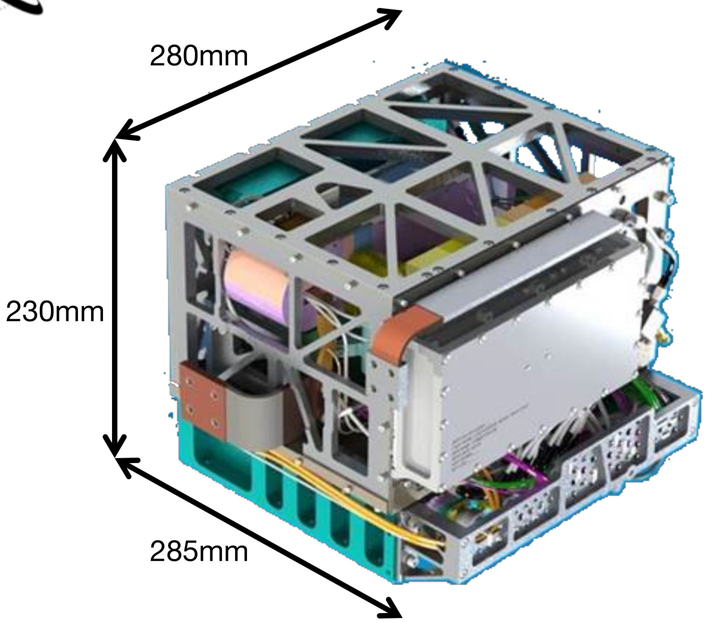
Deep Space Atomic Clock Project

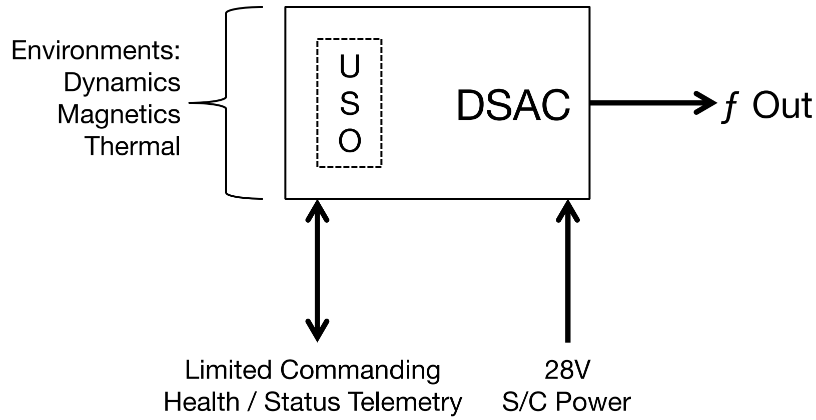
Implementation Uses

Deep Space Navigation	Science	Deep Space Timing	Autonomy	Near Space Navigation/Timing
NASA IND/DSN **NASA SMD/PSD**	**NASA SMD/PSD**	**NASA IND/DSN** **NASA SMD/PSD**	**NASA SMD/PSD**	**USAF – SMC/GPS** **USAF – MILSATCOM** **NRO**
• Multiple Spacecraft Per Aperture at Mars - doubles useful tracking • Full use of Ka-band tracking – OD uncertainty at Mars < 1 m (10 x improvement) • Outer planets users gain significant tracking efficiency – 15% at Jupiter 25% at Saturn	• Enhance gravity science at Mars, GRACE-level determination of long term gravity with one satellite, at Europa, flyby gravity objectives met robustly • Enhance planetary occultation science with 10 x better data	• Significantly reduce spacecraft timekeeping overhead • Improve reliability of critical time-dependent autonomous spacecraft functions • Reduce risks to long-term spacecraft hibernation	• Enables autonomous radio navigation (robotic and crewed) • Enhances EDL and precision landing • Key component to autonomous aerobraking • Coupled with OpNav, enhances primitive body exploration	• Diversifies clock industrial base - enhancing national security • Provides needed time accuracy/ stability for next generation secure communications • Significant aid to users with compromised GPS visibility – need only 3 in-view to position

For More Information, Contact: Allen.H.Farrington@jpl.nasa.gov, Website: http://www.nasa.gov/mission_pages/tdm/clock/

Core Technology At Scale – Demo Electronics and Packaging At TRL7





DSAC is a small, low-mass mercury-ion clock suitable for deep space flight with limited interfaces

Depending on intended use, environments, etc…two options for implementation exist:

Option 1 (DSAC "As-Is"):	SWaP (17kg, 56W w/USO), GEVS Dynamics
Option 2 (DSAC Reduced):	Re-package Electronics to reduce SWaP to 10kg, 30W

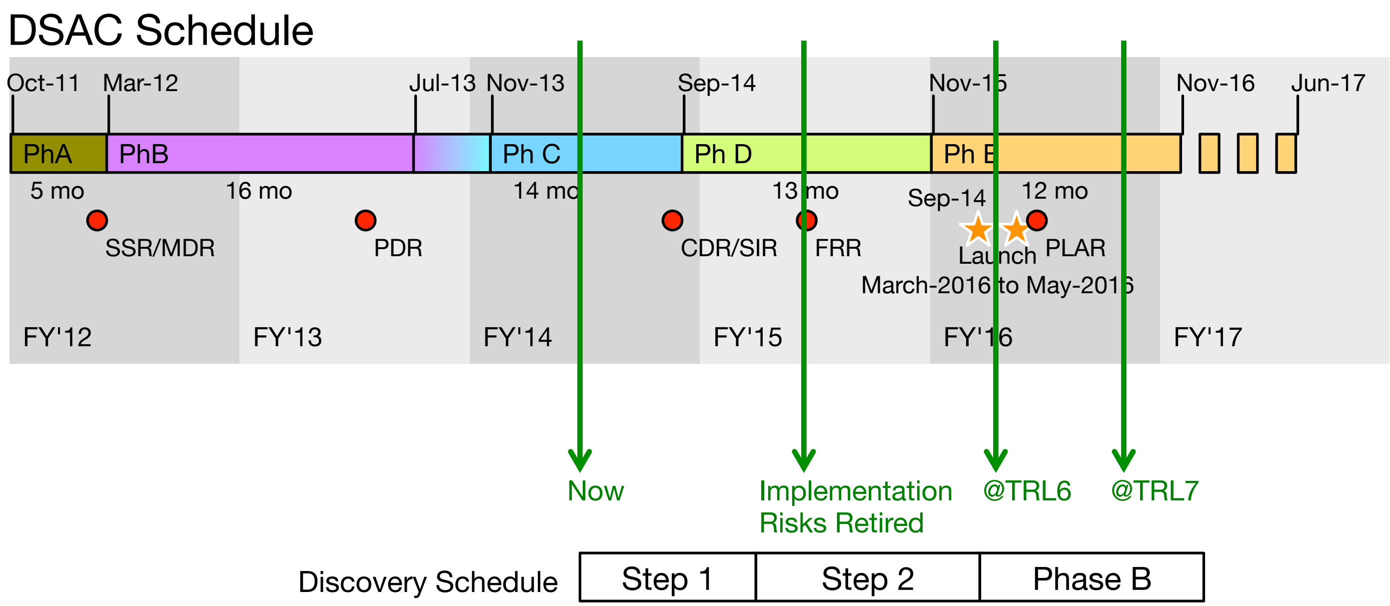
For both options, analysis of environments and lifetime would be required
For both options, analysis of short-term (USO-based) stability is required

TRL 7 Definition for DSAC

	TRL 7 defined for the *Deep Space Atomic Clock TDM*
Capability *performance against need*	Demonstrated capabilities against formal requirements. Assessment of demonstrated capabilities against future mission needs.
SWaP *Volume, Mass, Power*	Physics package at SWaP on track for future mission needs. Support Electronics and packaging to meet demonstration flight needs only.
Model Fidelity *What is flown?*	Advanced Prototype. Physics Package in the near-final configuration. Support Electronics suitable for demonstration mission only.
Critical Engineering *How much NRE Remains?*	Designed with flight rules and guidelines. Materials and Process controls. Mostly flight parts, some with flight potential (fly lower screening grade).
Environments	Testing to demonstration mission requirements only. Assessment against future mission needs as can be defined.
Reliability *Lifetime, Parts, Analyses, QA*	Focus on design margins verification and lifetime. Lifetime assessment against 15 year goal.
Validation *How are the L1 Requirements Verified?*	Verified against formal requirements for the demonstration mission only. Formal assessment against future mission needs that can be identified.

Deep Space Atomic Clock Project

Schedule Alignment with Discovery



DSAC is phased in advance of Discovery Needs Offering low implementation risk.

AO Information Package Contents: Identical to Electra Contents

DSAC Content	Detail
General Information	
Description of arrangement with NASA	Agreement Letter
Points of Contact	Project & Technical
Payload Description	
Description of technology development	Based on DSAC Infusion report
List of advantages offered	Based on DSAC Infusion Status Briefings
High-level description of components	No ITAR-restricted Data
General explanation of operating principles	Yes
Image of payload	Current DSAC Configuration
Simple block diagram of payload	Yes, Including Interfaces
Table of key specifications	Yes (CBE)
Table of payload-spacecraft bus interfaces	Yes (ICD)
Description of sensitivities/considerations	Yes

ROM Accommodation Cost

- To a S/C, DSAC is a simple, Power-In, Reference Frequency Out Device
  - Limited Commanding or Health and Status Telemetry Monitoring

- Based on Similar Devices (USO's)
  - The Accommodation Cost is would be based on these considerations:
    - Systems Engineering
      - Selection of USO Characteristics – Base Frequency & Short-term Stability
      - Integration with Telecom System
      - Fault Protection Considerations (if tied to Telecom System)
    - Thermal / Magnetic Environments for optimum performance (if necessary)
      - Only required for the highest performance (E-15 level AD) cases
    - System-level Integration & Test

Points of Contact

- For Program/Project and Implementation Items
  - Allen H. Farrington – DSAC Project Manager, Allen.H.Farrington@jpl.nasa.gov, 818-653-2284

- For DSAC Capabilities, Navigation and Scientific Uses
  - Jill Seubert, Jill.Tombasco@jpl.nasa.gov, 818-354-4076

- Jill and Allen are the “entry point” into working more closely with the DSAC/JPL team.
  - Jill and Allen work non-exclusively with all teams while protecting their information from being passed to any other proposal team.
  - The DSAC team and associated SME’s are a small group
    - The SME’s will work for all proposals – briefed on how to prevent COI and how to compartmentalize information about one proposal versus another
    - DSAC Project-Generated Technology and Advancements available to all proposals
      - DSAC is continuing to make progress and advancements and will feed that to all proposers working with us during Steps 1 and 2