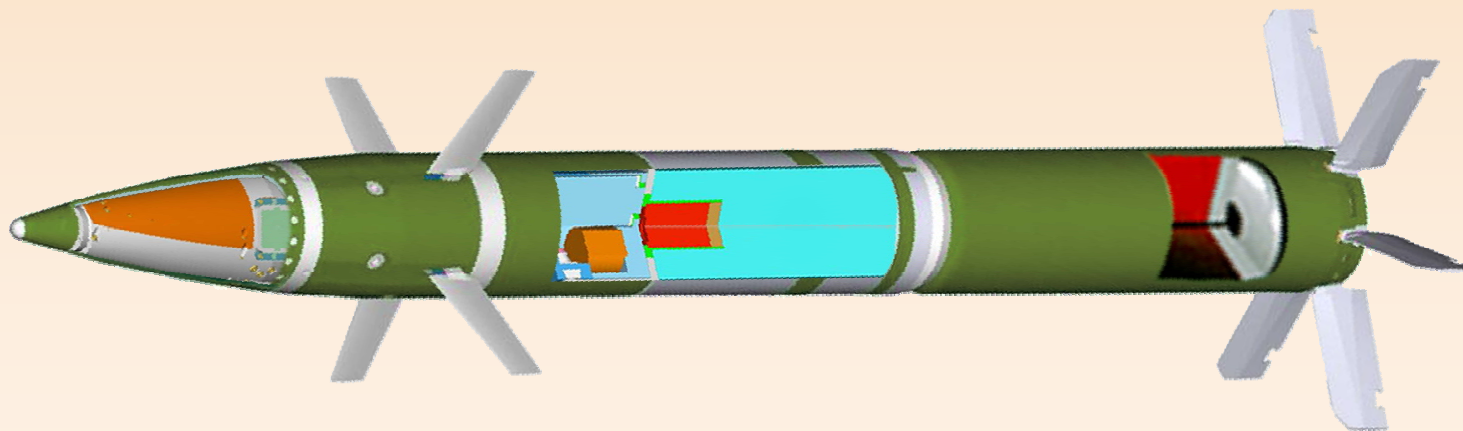# Inductive Interface for ERGM GPS Guided Projectile – Background and Test Results
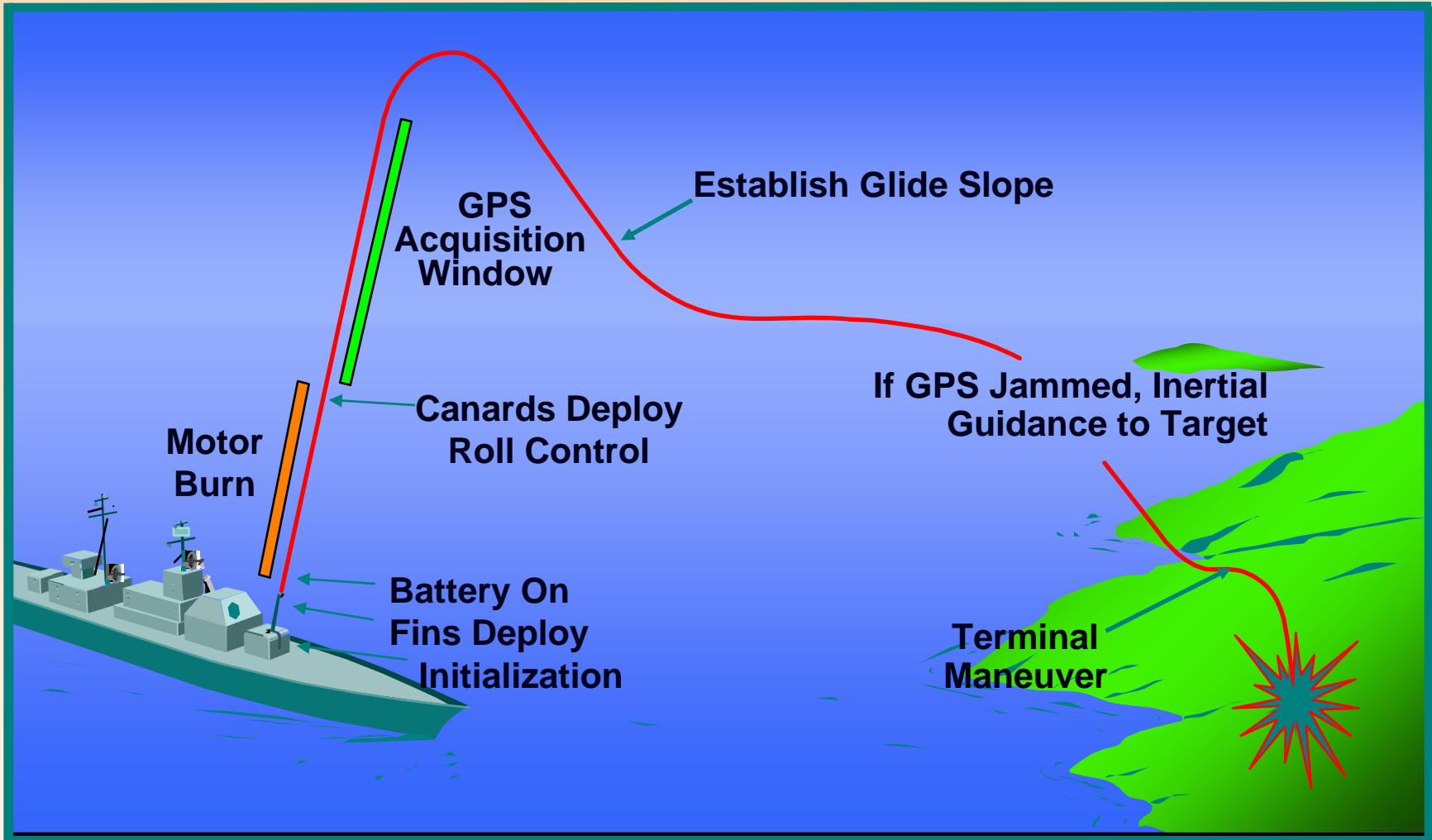
NDIA Gun & Missile Systems Conference
Sacremento, CA   27 – 30 March, 2006

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ERGM Flight Sequence

Establish Glide Slope

GPS Acquisition Window

If GPS Jammed, Inertial Guidance to Target

Canards Deploy
Roll Control

Motor Burn

Battery On
Fins Deploy
Initialization

Terminal Maneuver

- **Improved for Extended Range Projectiles and High Energy Propelling Charge**

New Inductive Setter for Guided Projectiles

Driving Requirements
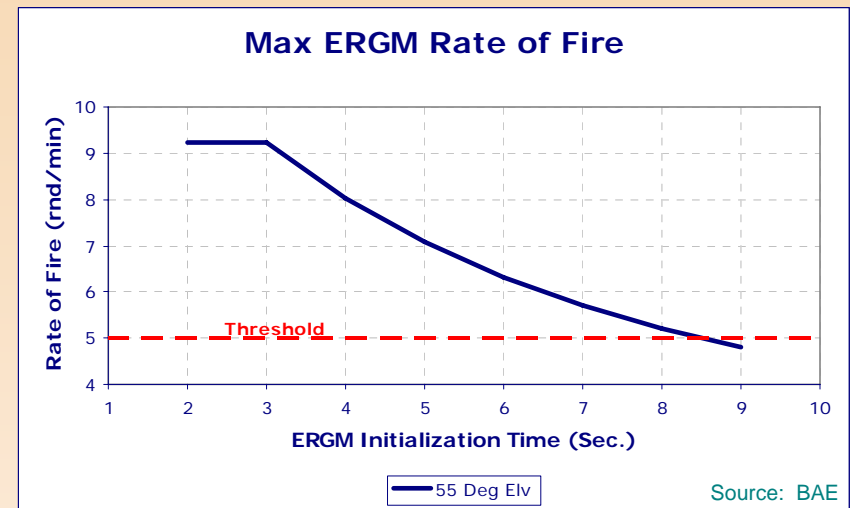
- **ERGM is stored as a wooden round. To ready for flight:**
  - **Perform self test**
  - **Transfer target and Ownship information**
  - **Load GPS cryptokeys**
  - **Prepare GPS for fast acquisition**
- **Similar process to other GPS weapons, except:**
  - **No umbilical**
  - **No GPS lock prior to launch**
  - **Harsh gun environment**
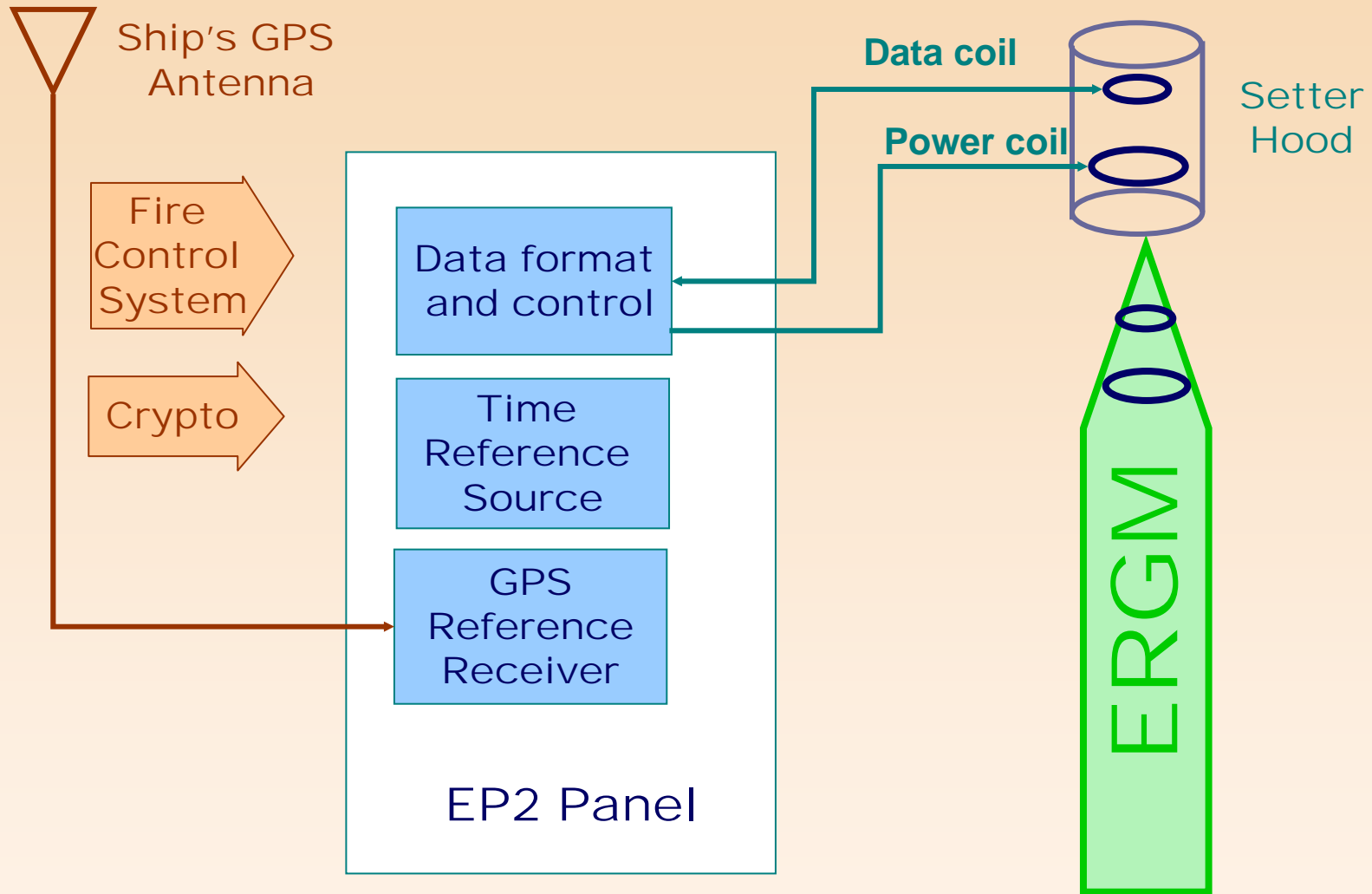- **Must be done in minimal time to allow for high rate of fire.**

Data Communication Interface Requirements

- **Gun System Rate Of Fire Dependent On ERGM Initialization Time.**

- **Support GPS Hot Start / Direct P(Y) acquisition:**
  - **Special data and time pulse requirements.**
  - **Adhere to NSA guidelines for crypto.**

- **Requirement derived from historical Mk34 Fuze Setter Requirement.**

- **High Rate of Fire allows for Multiple Round Simultaneous Impact (MRSI)**

Max ERGM Rate of Fire

Rate of Fire (rnd/min) vs ERGM Initialization Time (Sec.)

Threshold

— 55 Deg Elv

Source: BAE

Data Communication Interface Concept

Ship's GPS Antenna

Fire Control System

Crypto

EP2 Panel

- Data format and control
- Time Reference Source
- GPS Reference Receiver

Data coil

Power coil

Setter Hood

ERGM

DCI Overview

- **Provides power and two way serial communication via a dual coil design.**
- **Power:**
  - **20 kHz 50% duty cycle power waveform.**
  - **Designed for 80 Watts (60 W spec, 44 W typical in practice).**
- **Data:**
  - **500 kHz Manchester encoded data.**
  - **Gun is Master / ERGM is Slave.**
  - **Cyclic Redundancy Check (CRC) on all data except Crypto.**
  - **Crypto message block, is checked for proper size.**
  - **Analysis indicates bit error rate (BER) of 0.02% needed for rate of fire timeline.**

- **30,000 bits defined in WS33710. Smaller subset of those deemed required for ERGM initialization.**
- **Data contents:**
  - **Target location (repeated back for safety)**
  - **Warhead mode (HOB or point detonate)**
  - **Ship's own position, velocity**
  - **Gun bearing, elevation, muzzle velocity estimate.**
  - **GPS Ephemeris and Crypto variables**
  - **Time of Day**
  - **Time of arrival (only required for MRSI)**
  - **GPS Almanac (not required)**
  - **Meteorological data**
    - Surface winds, air temp, pressure (not required)
    - Winds aloft (not required)
  - **Preplanned Waypoints (reserved for future use)**

GPS Hot Start Drives Interface Design

- **A typical GPS receiver can perform a cold start:**
  - Acquire C/A code (unencrypted, 1 msec repeat).
  - Demodulate GPS data stream (**12.5 minutes**). ◄ Exceeds ERGM flight time.
  - Pull time of day from data stream.
  - Handover to P(Y) encrypted military signal. ◄ Direct Y required by performance spec
  - Triangulate own position.
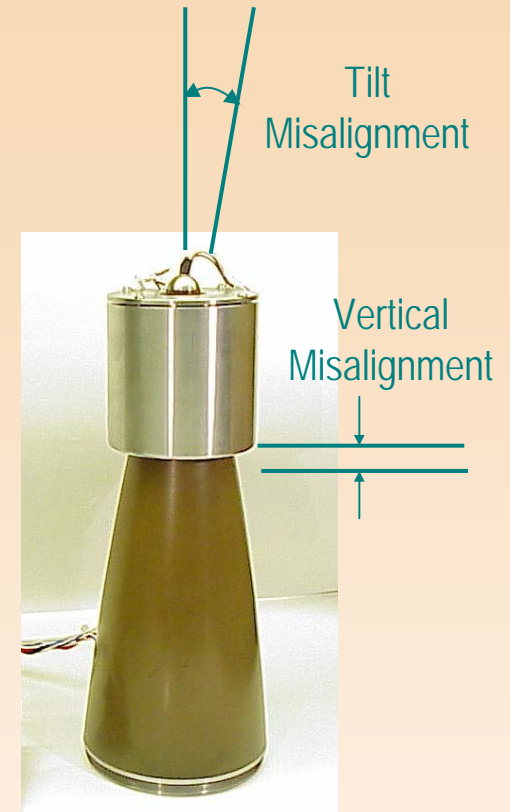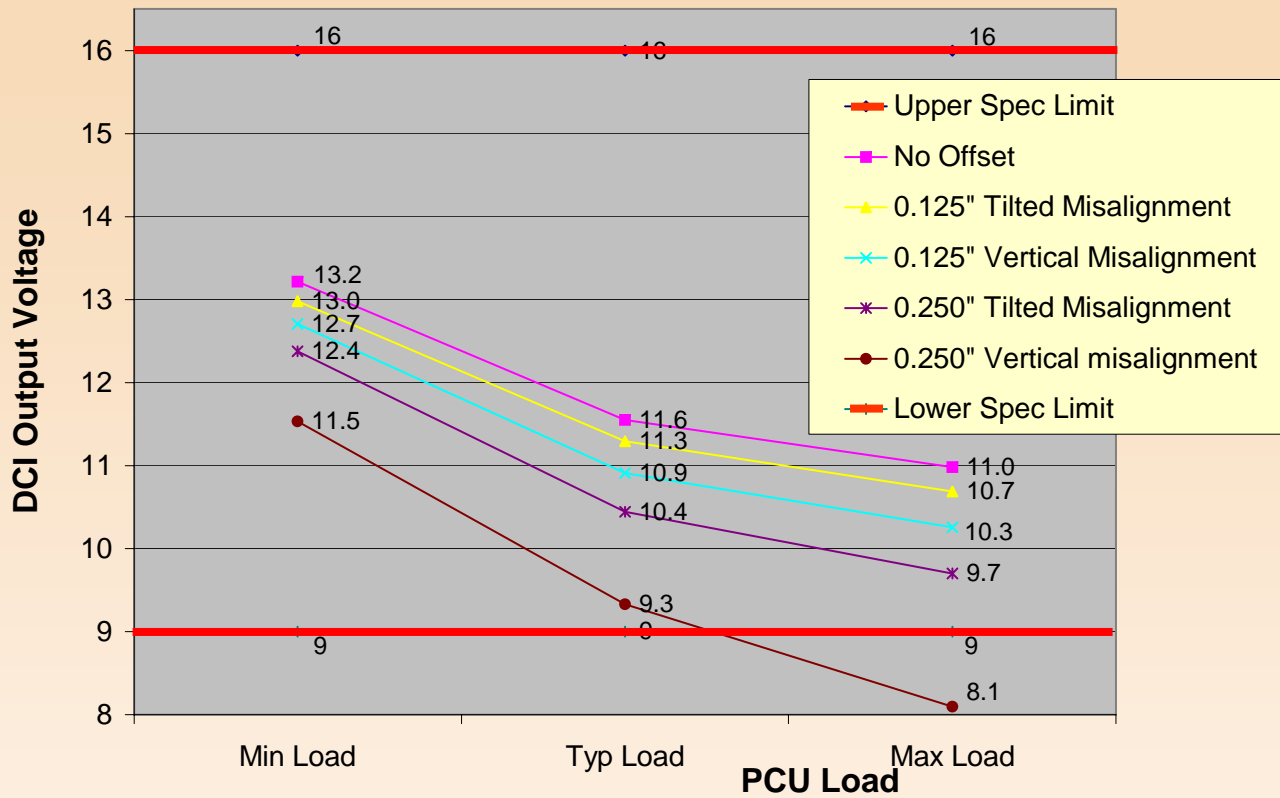
- **A hot start can occur when the receiver has been previously tracking or is initialized with current data.**
  - Known time of day (to a few tenths of a millisecond).
  - Known last position (to nearest kilometer).
  - Data stream content (ephemeris for all satellites in view).
  - Directly acquire P(Y) code.

> ERGM interface designed to provide all data necessary to allow round to perform a hot start
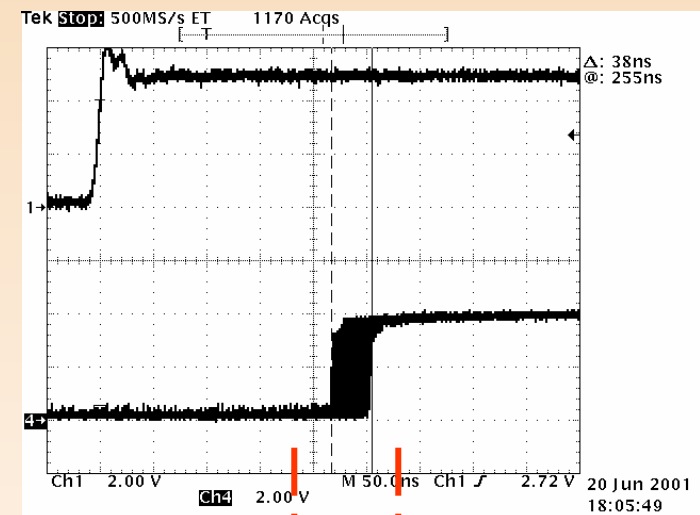
Misalignment Testing

Legend:
- Upper Spec Limit
- No Offset
- 0.125" Tilted Misalignment
- 0.125" Vertical Misalignment
- 0.250" Tilted Misalignment
- 0.250" Vertical misalignment
- Lower Spec Limit

Y-axis: DCI Output Voltage
X-axis: PCU Load (Min Load, Typ Load, Max Load)

Data values shown:
- Min Load: 16, 13.2, 13.0, 12.7, 12.4, 11.5, 9
- Typ Load: 16, 11.6, 11.3, 10.9, 10.4, 9.3, 9
- Max Load: 16, 11.0, 10.7, 10.3, 9.7, 8.1, 9

Tilt Misalignment

Vertical Misalignment

DCI Output Voltage Regulation Shown to Perform Beyond Limits of Expected Misalignments

Time Mark Jitter

- **Time Mark Pulse – provides time and frequency reference:**
  - **Aligned to GPS Time "1 second rollover" to within 1 microsecond – (no decimal places in time field beyond "tenths" required).**
  - **Interleaved with data. Gun plans for a break in data every 1/10 second to allow pulse to come thru.**
  - **Low jitter (+/- 50 nsec) requires local pulse source (difficult requirement for ship system to meet).**

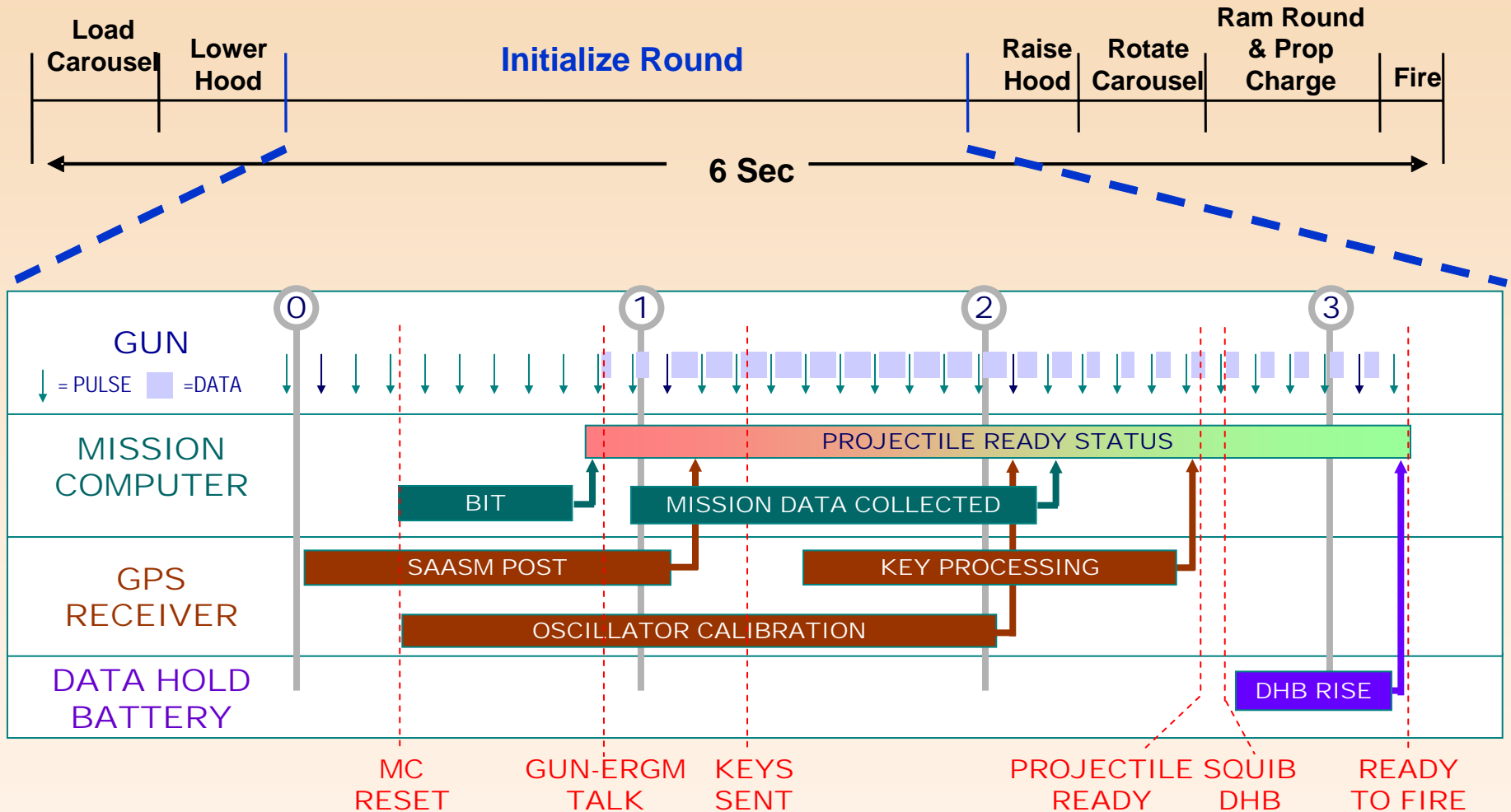**Example of jitter testing with prototype hood and coils**

Tek Stop: 500MS/s ET   1170 Acqs

Δ: 38ns
@: 255ns

Ch1 2.00 V   Ch4 2.00 V   M 50.0ns Ch1 ∫   2.72 V   20 Jun 2001
18:05:49

+/- 50 nsec requirement

Initialization Timeline

Gun System Firing Timeline

| Load Carousel | Lower Hood | Initialize Round | Raise Hood | Rotate Carousel | Ram Round & Prop Charge | Fire |

6 Sec

GUN

↓ = PULSE ▮ =DATA

MISSION COMPUTER

PROJECTILE READY STATUS

BIT

MISSION DATA COLLECTED

GPS RECEIVER

SAASM POST

KEY PROCESSING

OSCILLATOR CALIBRATION

DATA HOLD BATTERY

DHB RISE

MC RESET

GUN-ERGM TALK

KEYS SENT

PROJECTILE READY

SQUIB DHB

READY TO FIRE

- **Dec 2005**
- **Mk45 Mod 4 Prototype Gun**
- **Potomac River Test Range, Dahlgren, VA**
- **Combined effort with BAE and Raytheon participation**

- **ERGM In Loader Drum Environment With EP2 Tactical Software.**
- **Testing Conducted With Stand Alone ERGM And With PTS For Diagnostic Analysis.**

Blue denotes tactical configuration
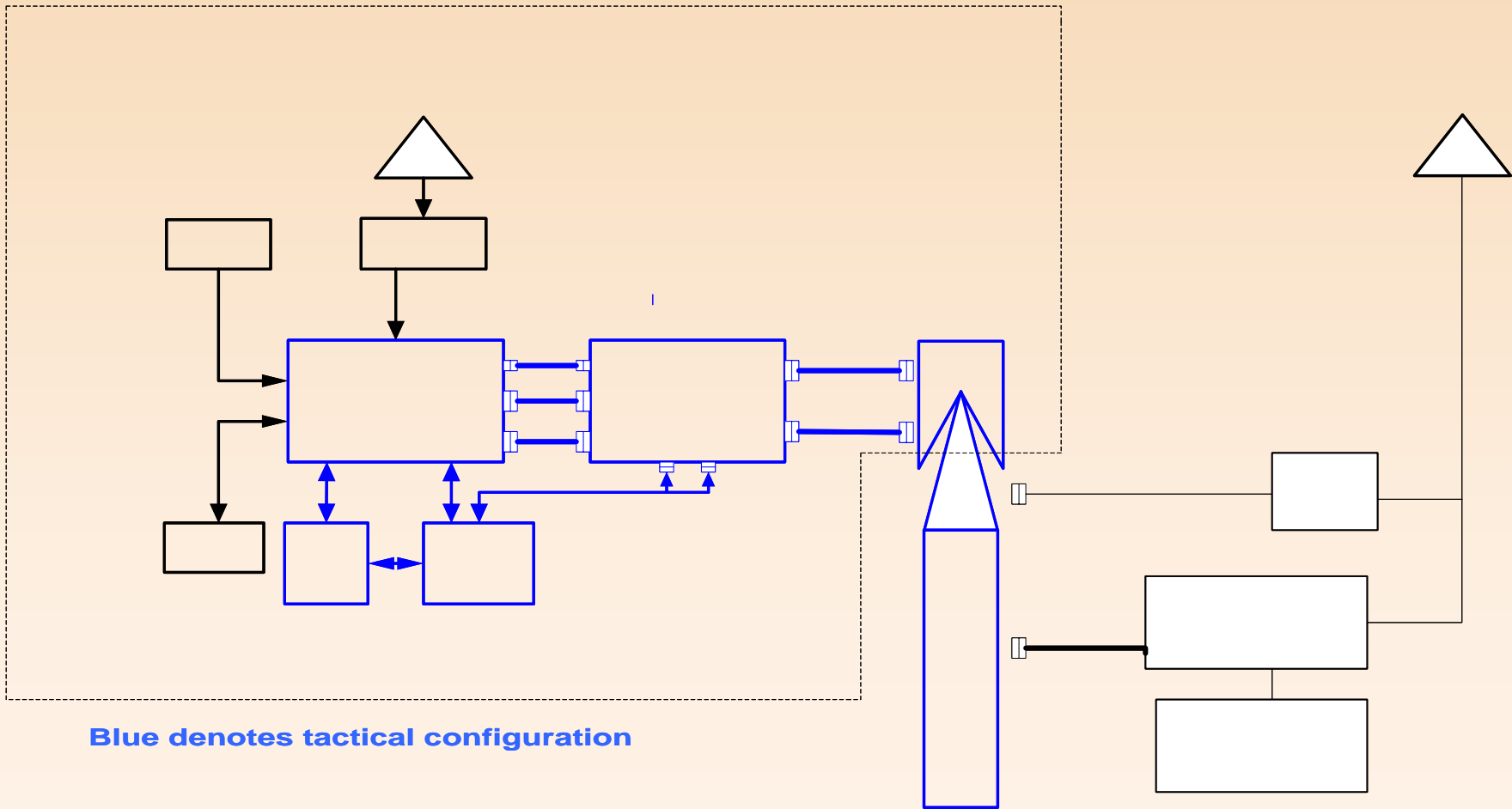
# Data Communications Testing Results

- **Repeatedly Achieved Projectile Ready Status In Less Than 3 Seconds.**

  - **Average Initialization Time Of 2.6 Seconds.**

  - **Successfully Demonstrated 13 Requirements Including Proper Time Transfer, Oscillator Calibration, Mission Data, Crypto Loading, Data Hold.**

  - **Verified Successful Initialization And Oscillator Cal With Direct-Y GPS Acquisition Post Data Hold Period.**

ERGM Setting Times
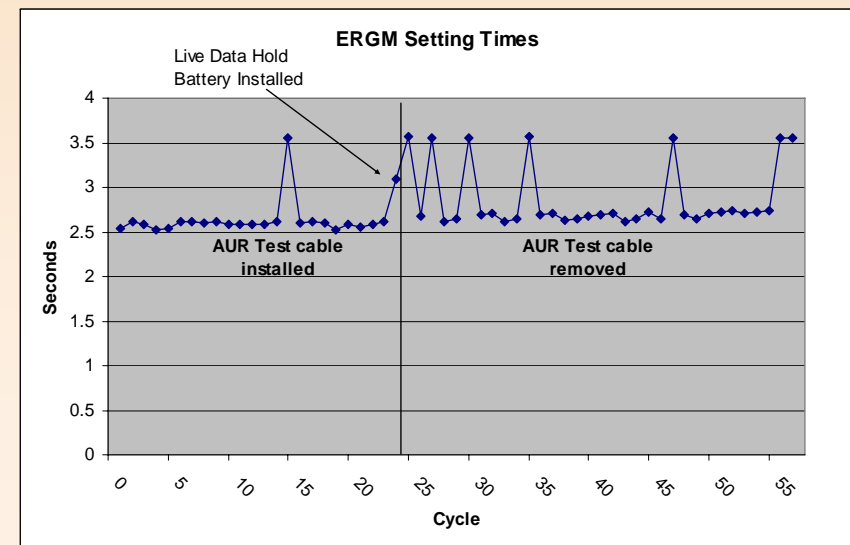
Clock Calibration

- **Allocation for clock calibration at Initialization Station is 0.1 parts per million (PPM).**
- **Procedure: Initialize round, put into standby, acquire GPS, compare known freq offset (post track) and calibrated freq offset.**

**Demonstrated Calibration in parts per million**
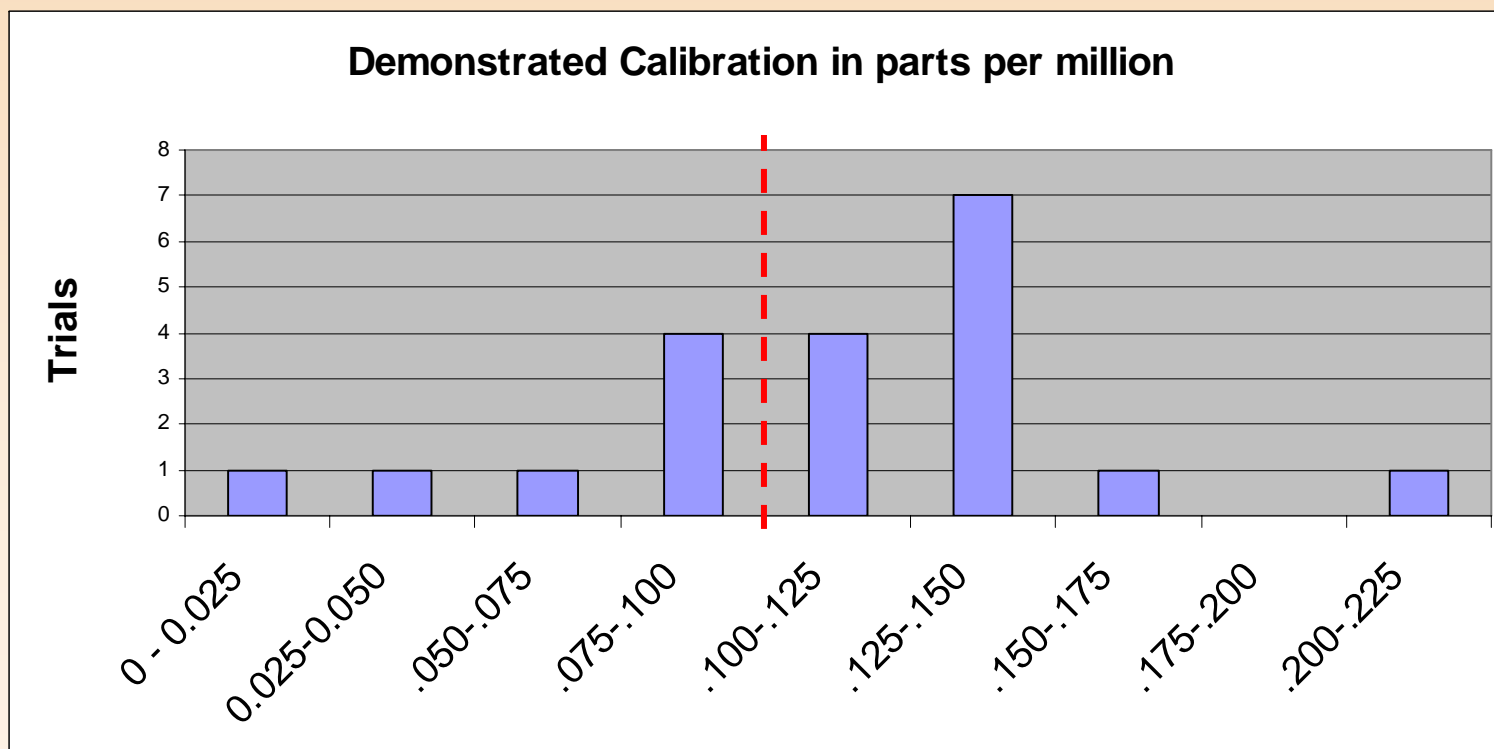
All but one of the trials with > 0.1 sec error had a standby time of 125 seconds.
Additional error can be attributed to clock oscillator drift (also within allocation)

Initialization Time

- **Majority of sets occurred within 3 seconds.**

- **Investigation of "flyers" is underway.**

- **Cycle with Data Hold Battery Squib event exceeded goal by 0.1 second (expected and allowed).**

Demonstrated Initialization Time
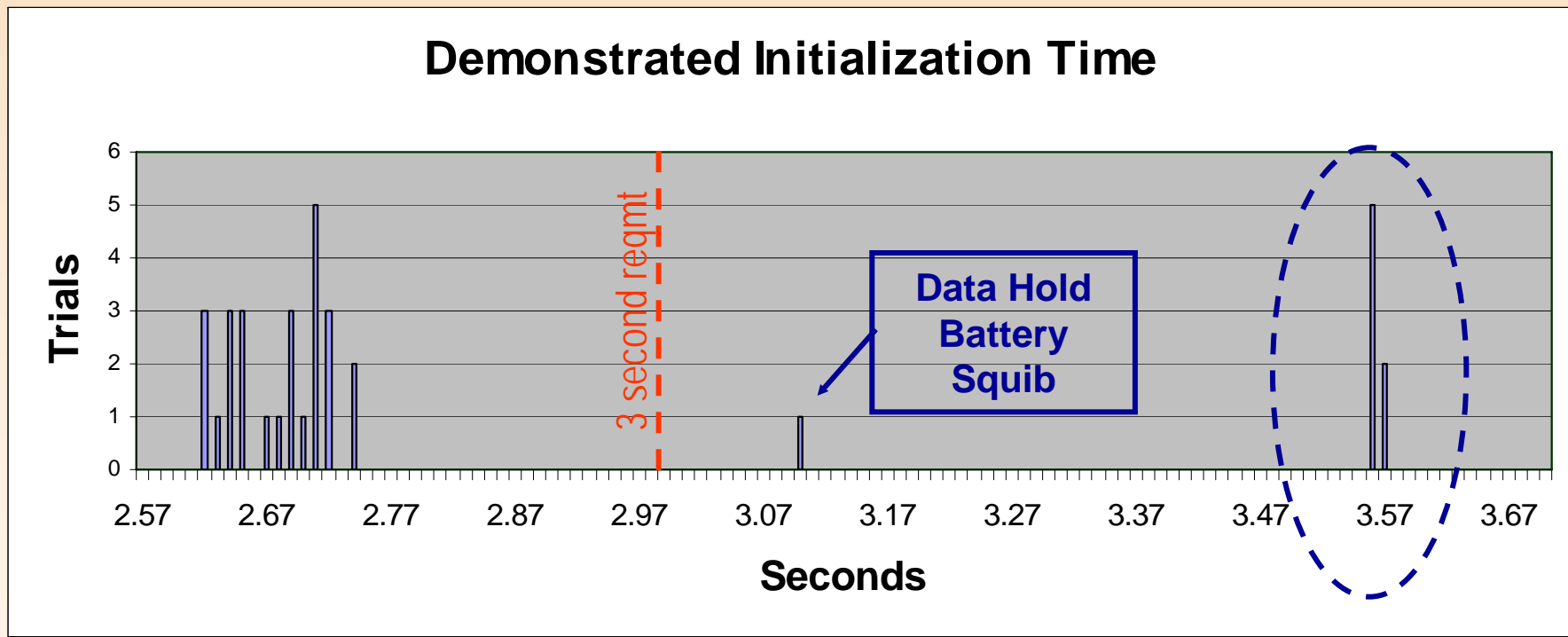
Conclusions

- **Solid technological advancement in state of the art in inductive setting.**

- **Demonstrated compliance with all requirements.**

- **Low risk to move forward to operational system testing.**

- **Thanks to Raytheon (Texas Instruments) and BAE (United Defense LP) for many years of innovation, cooperation and dedication. Its been a long time coming!**