ETF-WPML Instrumented Projectile

Michael Irwin
Naval Surface Warfare Center Dahlgren Division
michael.g.irwin@navy.mil
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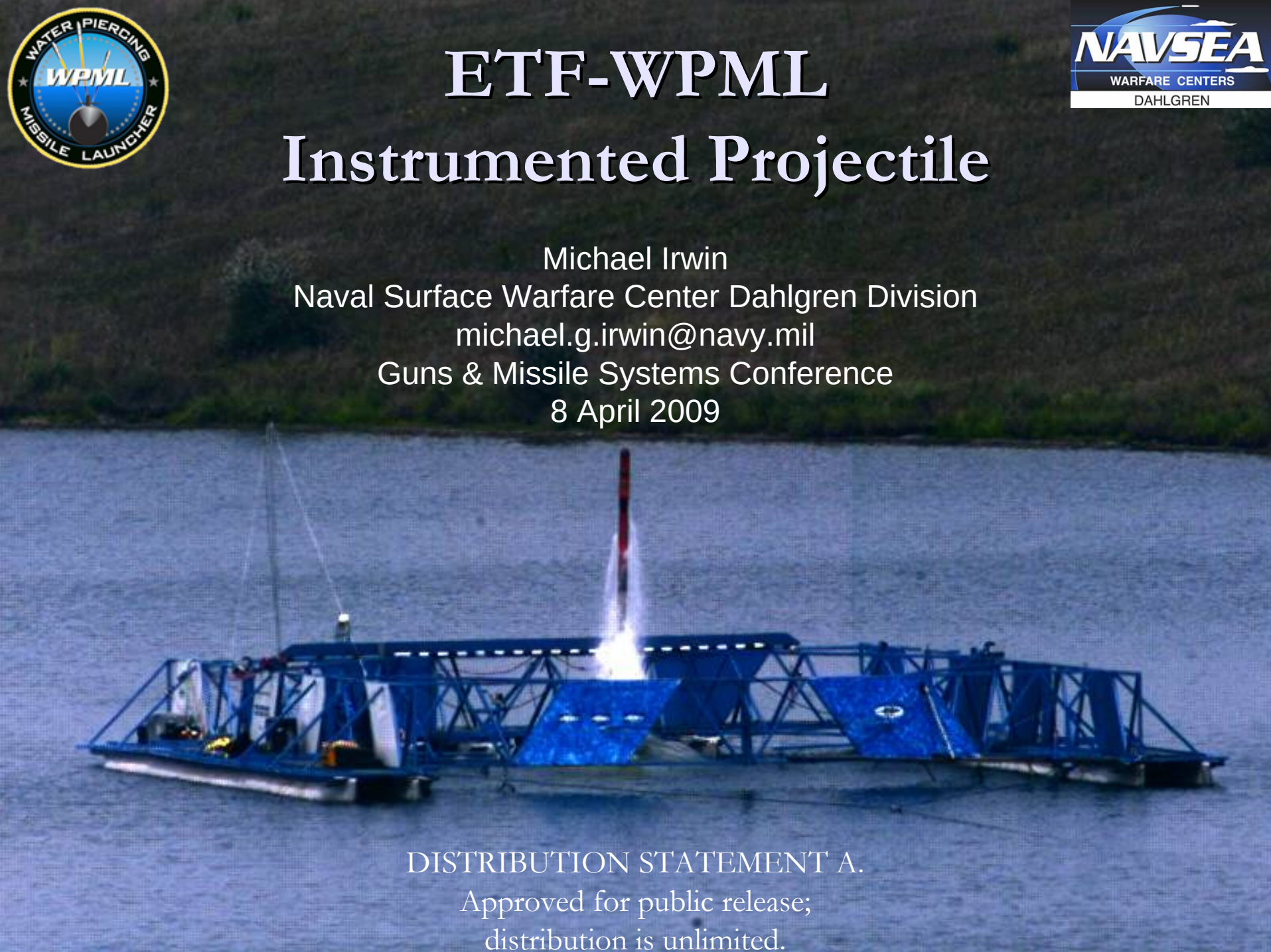
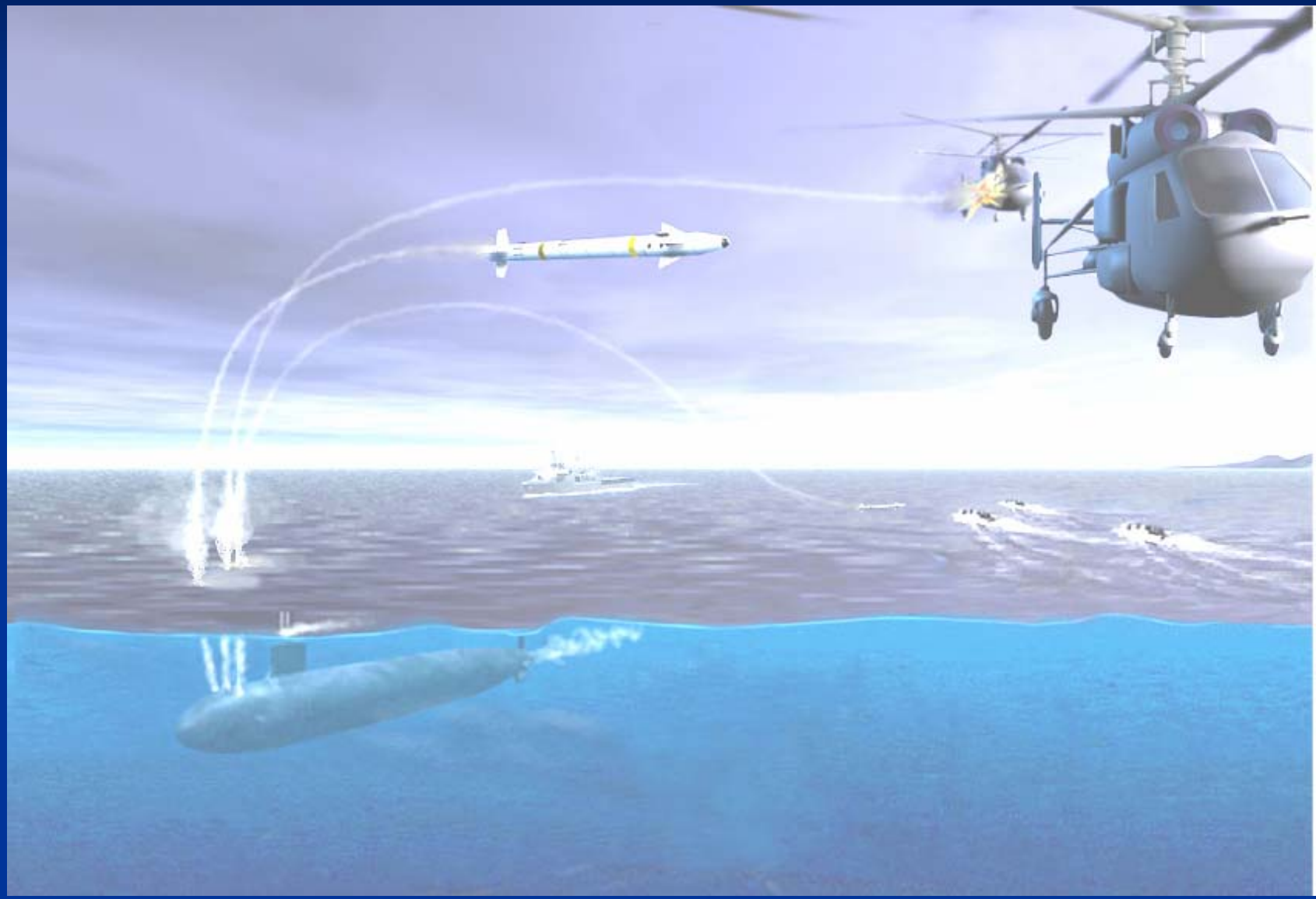


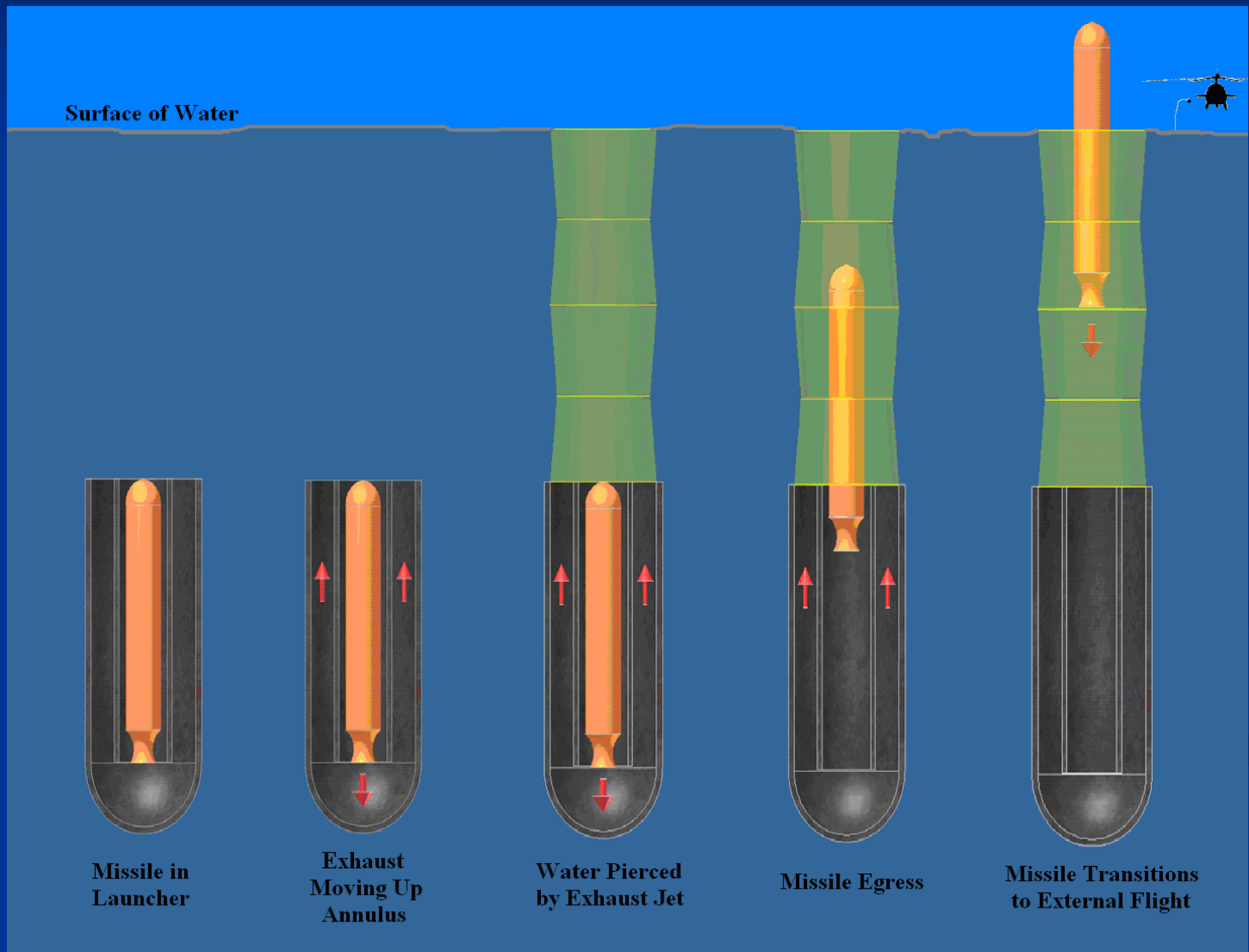
Overview

- WPML (Water Piercing Missile Launcher) Overview
- ETF (Electronic Test Fuze) Background
- ETF-WPML Design
- Test Results & Data Reduction
- FY09+ Efforts

WPML Concept



CCL
(Concentric Canister Launcher)



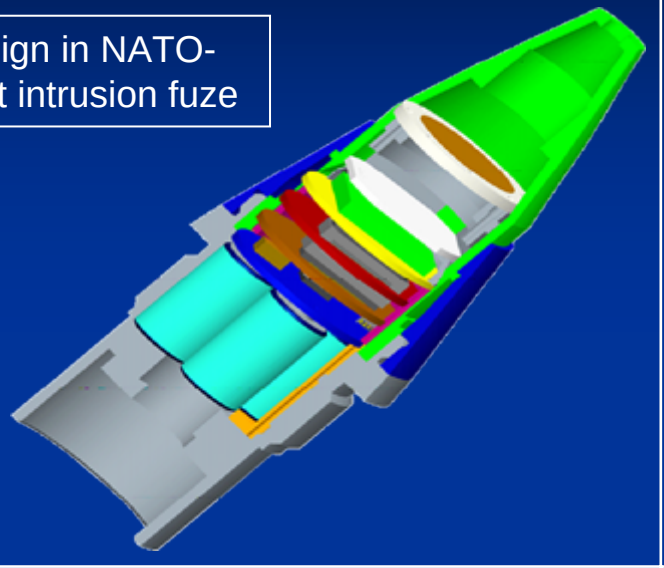
The Need for On-board Instrumentation

- Measure the missile's shock and vibration levels before release and in the plume
- Identify possible missile contact with water in the plume
- Identify possible tail slap during water exit
- Characterize the missile's rigid body motion

All of these require on-board instrumentation!

ETF – Electronic Test Fuze

Core ETF design in NATO-standard short intrusion fuze



Key Events / Milestones

Flight	Projectile	Charge	Location	Date	Met Objectives
ETF 1	155mm	7W	AA Fuze	8/06	Y
ETF 2 (IR link)	155mm	7W	AA Fuze	11/06	Y
ETF-GPS 1	155mm	7R	AA Fuze	4/07	Y
ETF-GPS 2	155mm	7R	AA Fuze	8/07	Y
ETF-ERGM 1-5	ERGM	EX167	WSMR	2/08	Y
ETF-GPS 3-4	155mm	7R	AA Fuze	5/08	Y
ETF-WPML 1	Missile Body	N/A	Crane	8/08	Y
ETF-WPML-2	Missile Body	N/A	Crane	11/08	Y

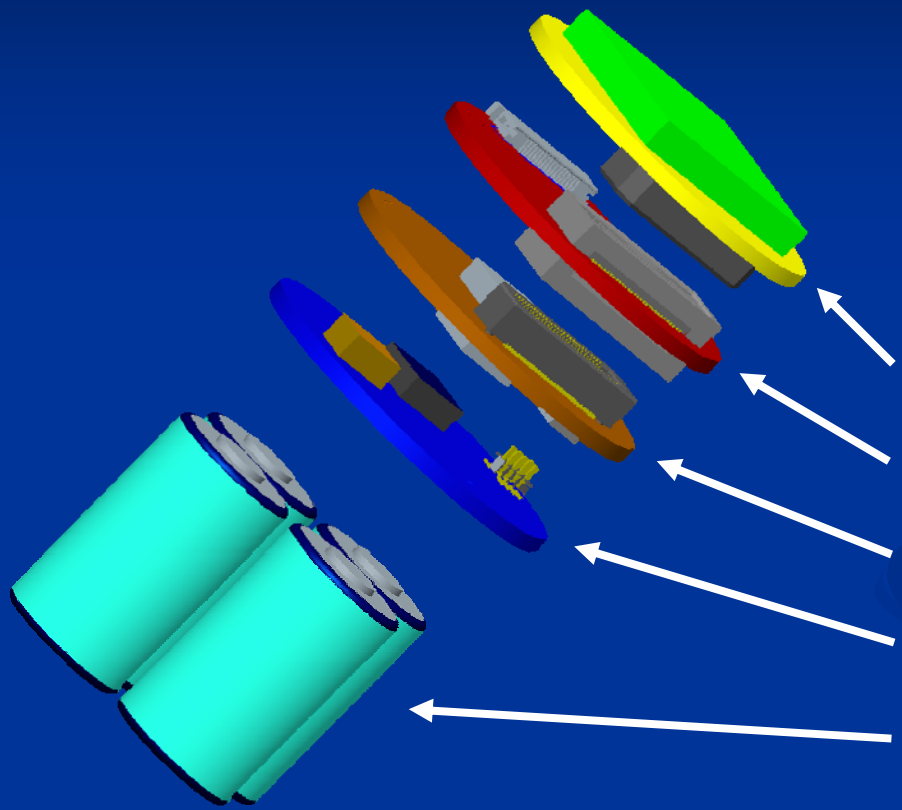
- Designed fully in-house at NSWCDL, G-33 (Precision & Advanced Systems Branch)
- Designed to support realistic gun-shock testing of myriad subsystems
- 1.5” O.D. Board Stack
- On-board sensors include a 3-Axis magnetometer and an axial 20 kG accelerometer
- 1 Mbps Telemetry Encoder, ½ Watt S-Band Telemetry Transmitter
- Easily configurable to support additional sensors or subsystems
- Designed and tested for 50kG shock survival
- All-up system successfully flight tested
  - 5-for-6 gunshots out of 155mm Howitzer to 9 kG
  - 4-for-5 ERGM flight tests to 10+ kG
  - 8-for-8 High-G tests
  - 2-for-2 WPML Instrumented Missile tests
- Core Stack with telemetry fits in NATO standard fuze form factor
- Costs including all HW, ME/EE Support, and data breakout
  - ~$10,000/per, basic ETF
  - +$1500/per ETF w/ low frequency, high-G triax accel
  - +$6,000/per ETF w/ high frequency, high-G triax accel

Sponsors: GIF, ERGM, WPML, others

Team Lead: Hamish Malin, G-33

Dahlgren Team: Marc Bassett, Michael Irwin, Travis James, Nathan Joswiak, and others depending on project

Board Stack - General



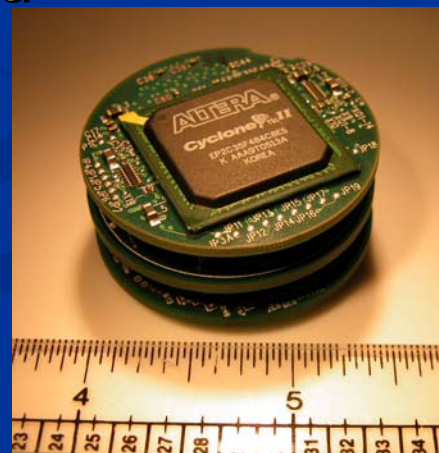
FPGA Board

FPGA I/O Support Board

Sensor Board

Power Board

Batteries



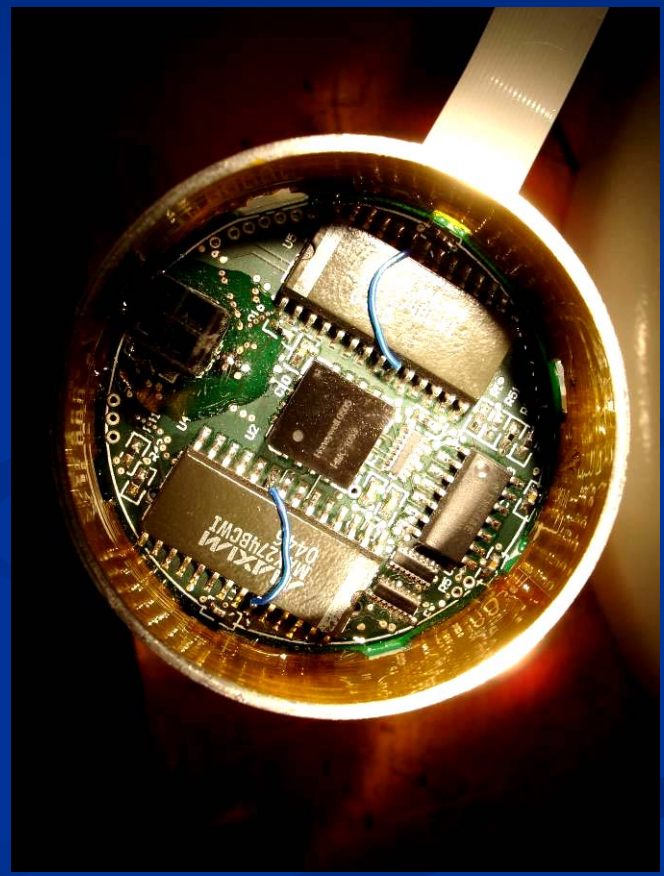
FPGA Board

- Interfaces with ADCs and sensors
- Controls & monitors various subsystems under test
  - HOB sensor
  - ElectRelease actuator
  - IR transceivers
  - GPS Rx
- Measures (time = 0) from forward-looking accelerometer
- Encodes test data into telemetry stream

FPGA architecture makes ETF adaptable for future tests

Sensor Board

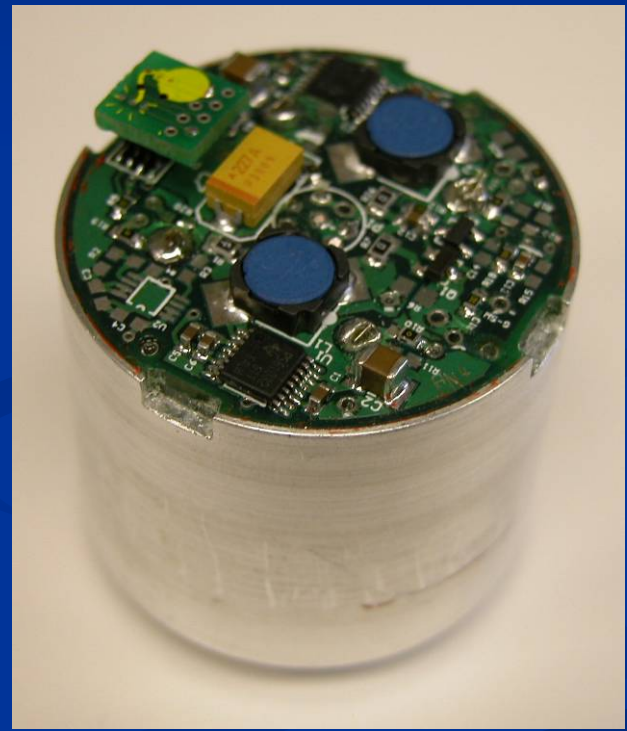
- Silicon Designs 20k-g 1-axis accelerometer
- Honeywell HMC 1053 3-axis magnetometer
- 2 Maxim MAX274 8th-Order Active Filters provide 2nd-Order Chebyshev LPF for each channel
- 2 12-bit, 8-channel TI ADS7852 ADCs sample at up to 32 ksps



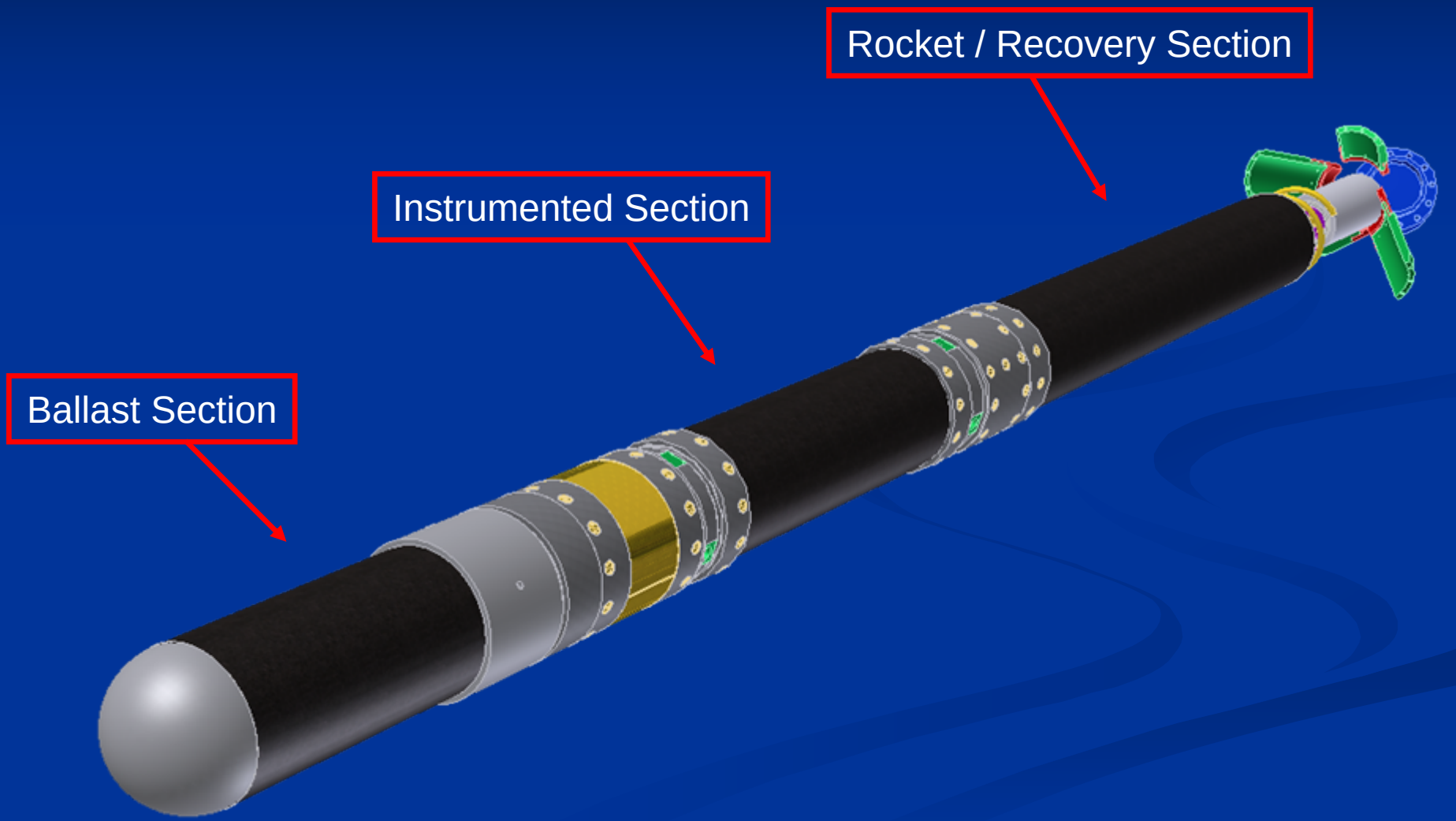
Vias available for additional external sensors

Battery Puck & Power Board

- Current configuration utilizes 4 CR2s
- Puck is designed to be removable such that fresh batteries can be used for flight
- Supplies 5V, 2A; 4V, 500mA
- Other voltages possible
- Current puck can power full ETF stack for > 2hrs

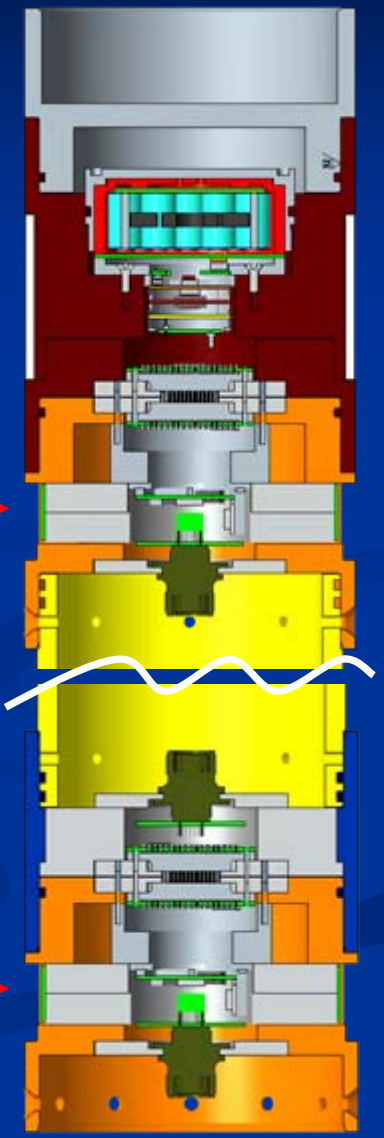


Projectile Overview



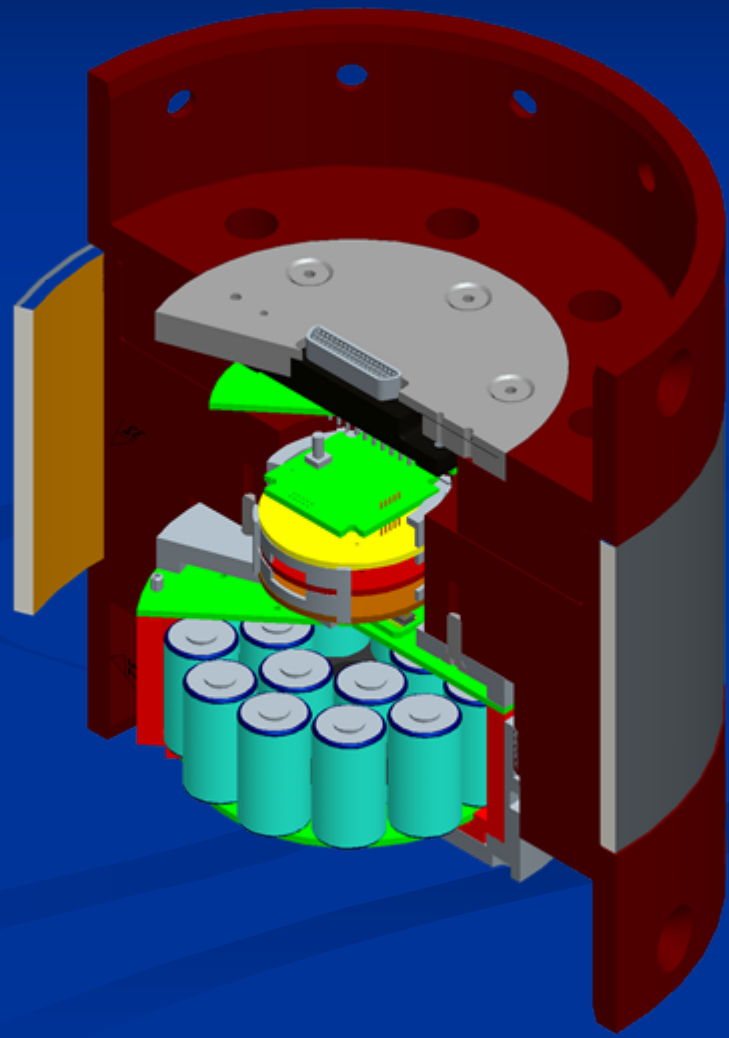
ETF-WPML Overview

- 1 core module, 2 sensor modules
- Core module has axial accelerometer
- Sensor modules have 3-axis accelerometers and moisture sensors



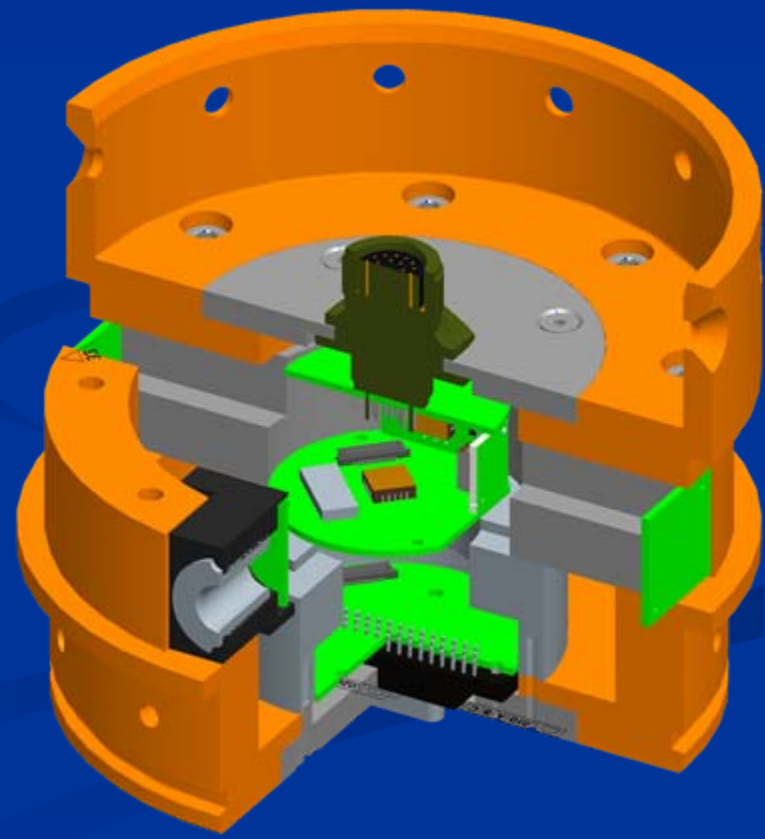
Core Module

- Core Module
  - Transmitter: MA06836-025
    - 2254.5 MHz, 500mW FM telemetry transmitter
    - Fired on M549 RAP, M795, M483, ERGM
  - “Core Stack”
    - FPGA Board
    - Support Board
    - Sensor Board
  - Power Module
    - Energizer CR2 Lithium Batteries
    - Similar assemblies fired on 155mm ammo up to 16 kG and 5” ERGM



Sensor Module

- Accelerometer Suite
  - 3x single axis sensors oriented in three primary axes
  - +/- 200G Max/Min Amplitude
  - 4 kHz sample rates
  - Anti-aliasing filters tuned to pass DC - 2kHz
- Water Sensors
  - 2x recessed, 2x on surface
  - Each element registers pass/fail
  - 1 kHz sample rates
  - Disabled on North module



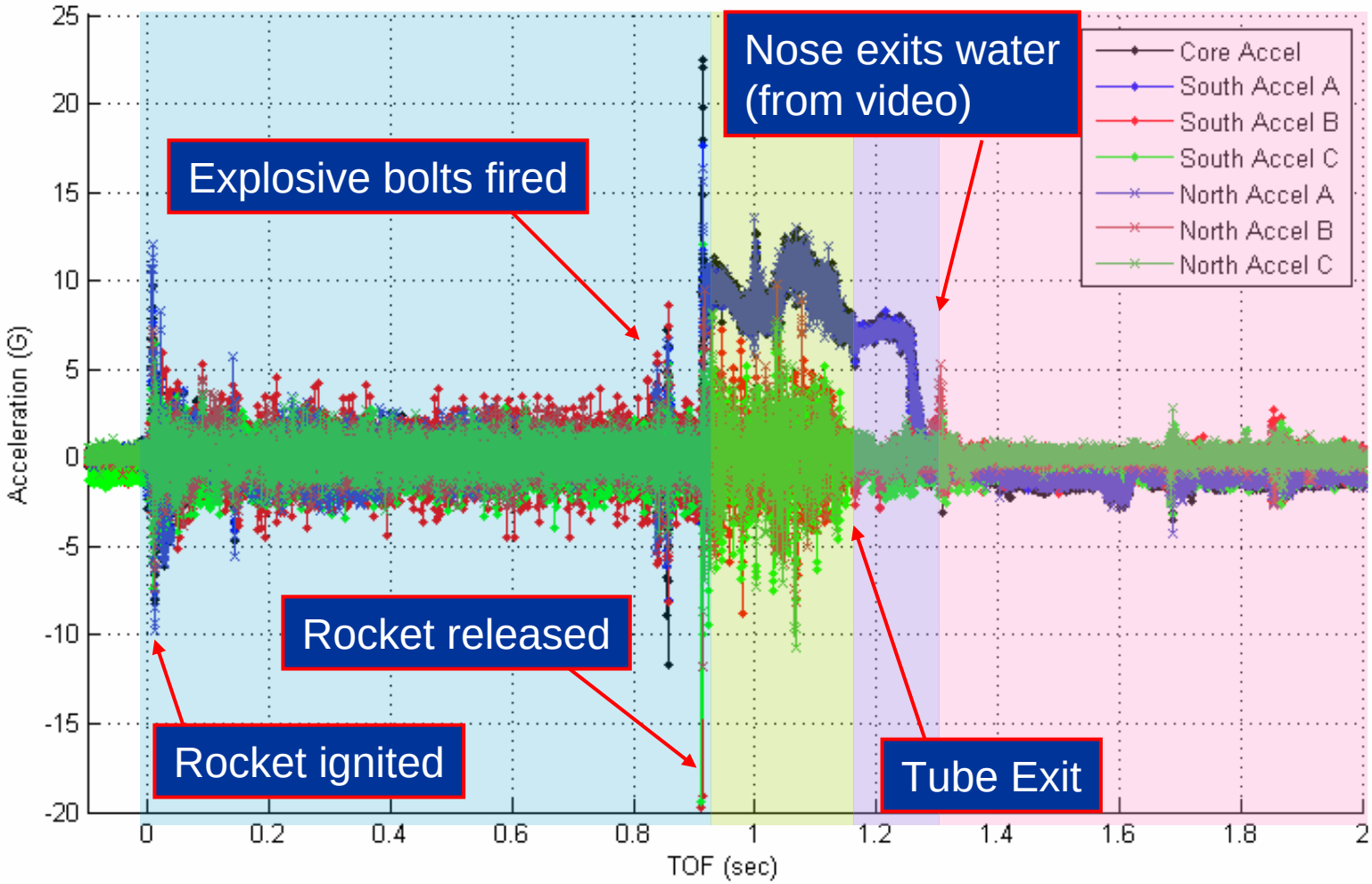
Translator

- Gondola supports CCL and missile underwater
- Translator supports gondola
- Translator is towed by boat to emulate submarine launch conditions

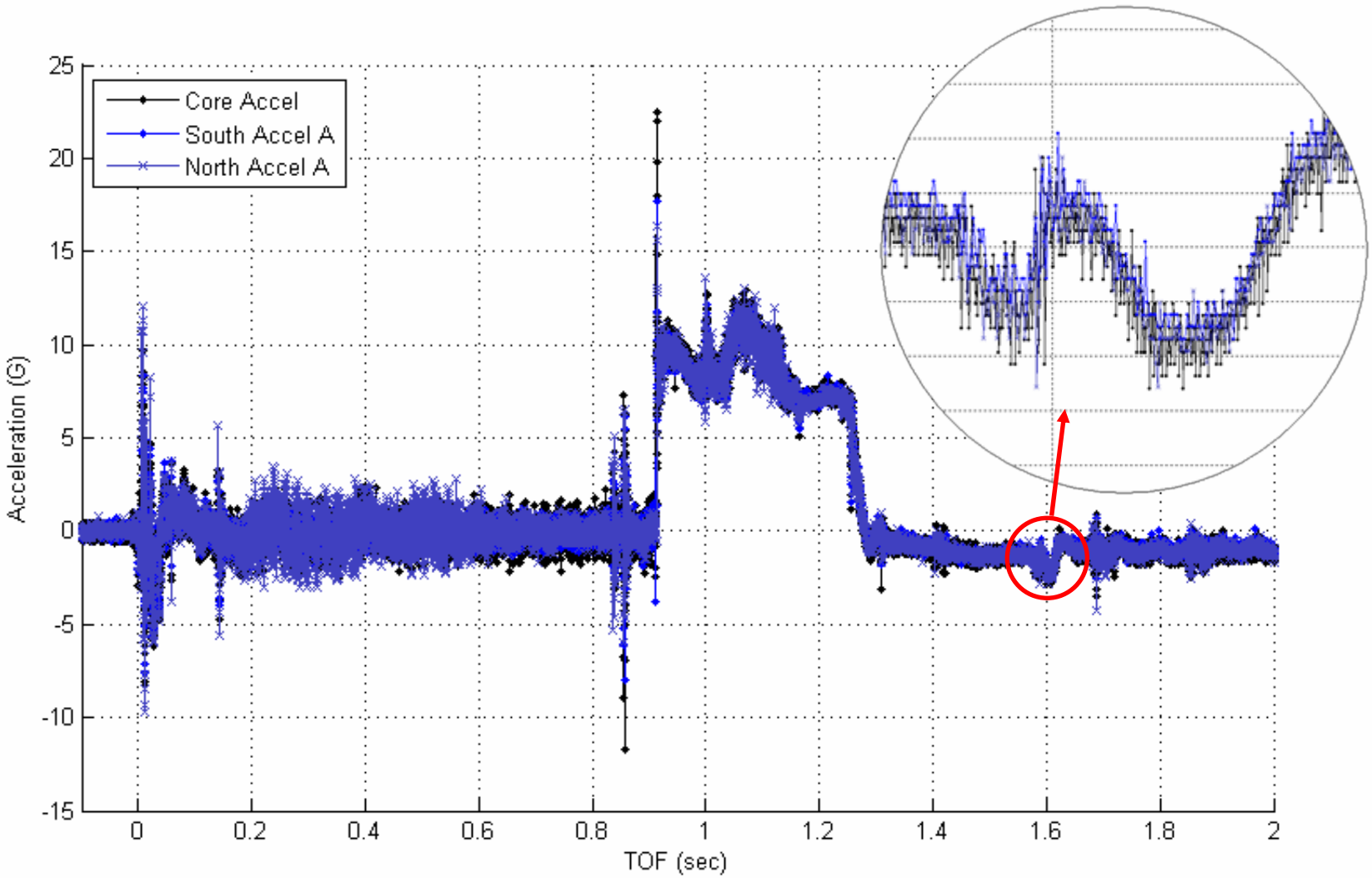
Lake Glendora Instrumented Test Summary

- June 2008
  - Did not launch (No test)
- August 2008 – 1 knot flyout
- November 2008 – 3 knot flyout

Accelerometer Data

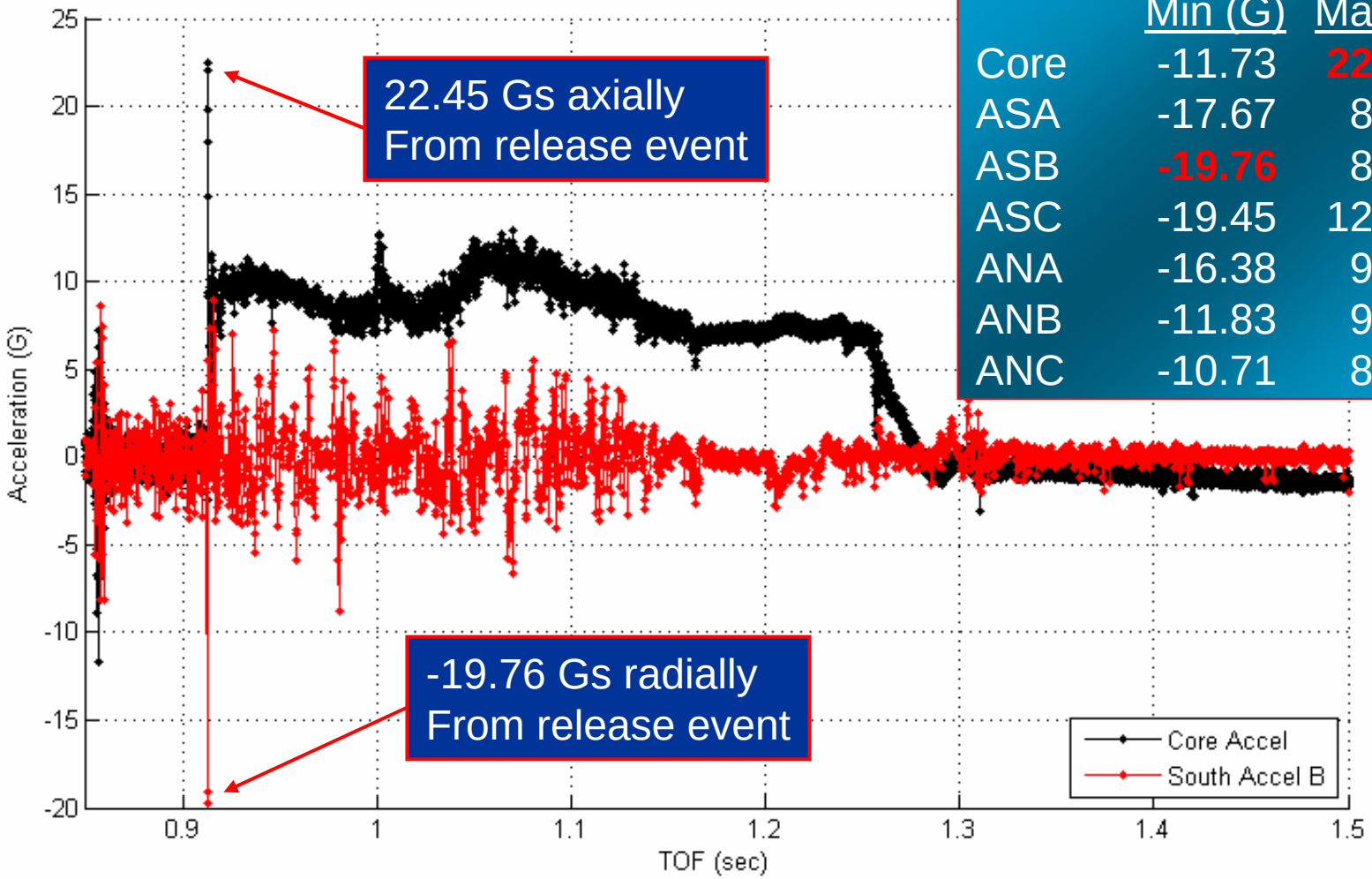


All three axial accels

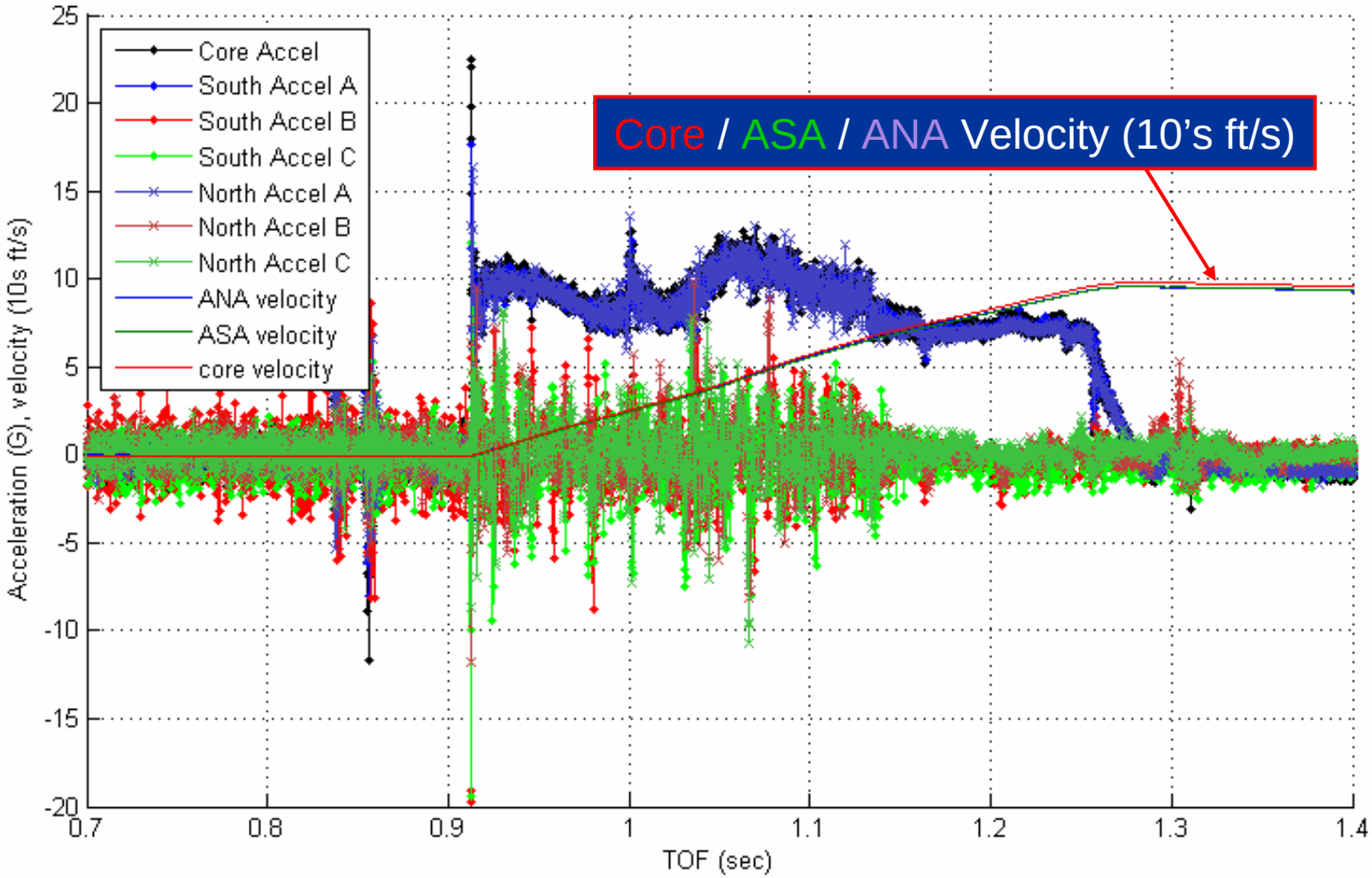


Maximum Measured Loads

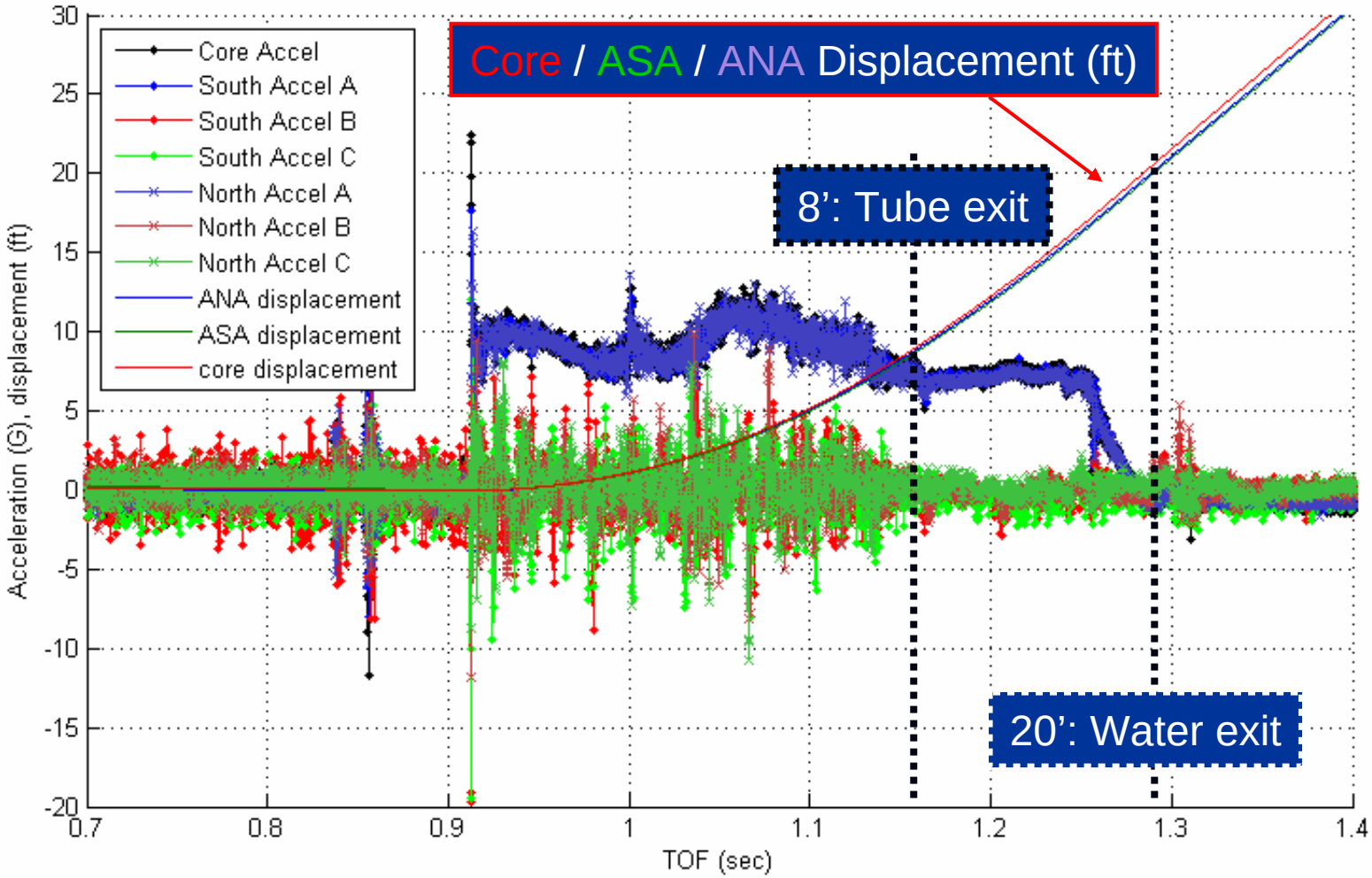
	Min (G)	Max (G)
Core	-11.73	22.45
ASA	-17.67	8.00
ASB	-19.76	8.94
ASC	-19.45	12.00
ANA	-16.38	9.72
ANB	-11.83	9.84
ANC	-10.71	8.14



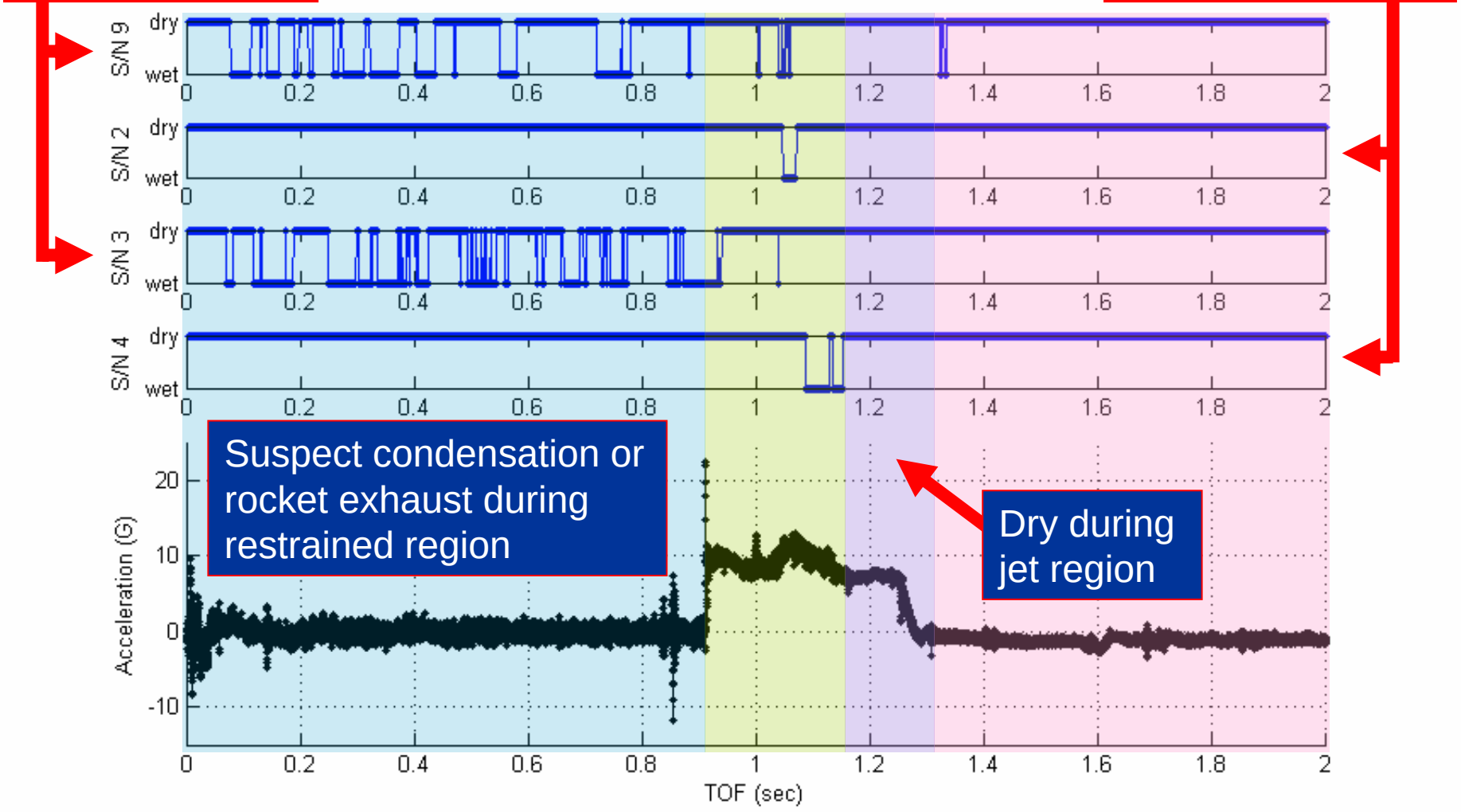
Axial Velocity



Axial Displacement



Moisture Sensors Overlay



ETF-WPML Summary

- ETF-WPML developed in-house, on-budget, and on-schedule
- Instrumented section survived and collected data as planned
- Hardware has been reused for multiple tests, and will be used again for future tests
- Data collected has helped both validate predictions and confirm overall launch survivability
- Sensors processed for rigid body motion; more sensitive parts required for complete 6DOF solution

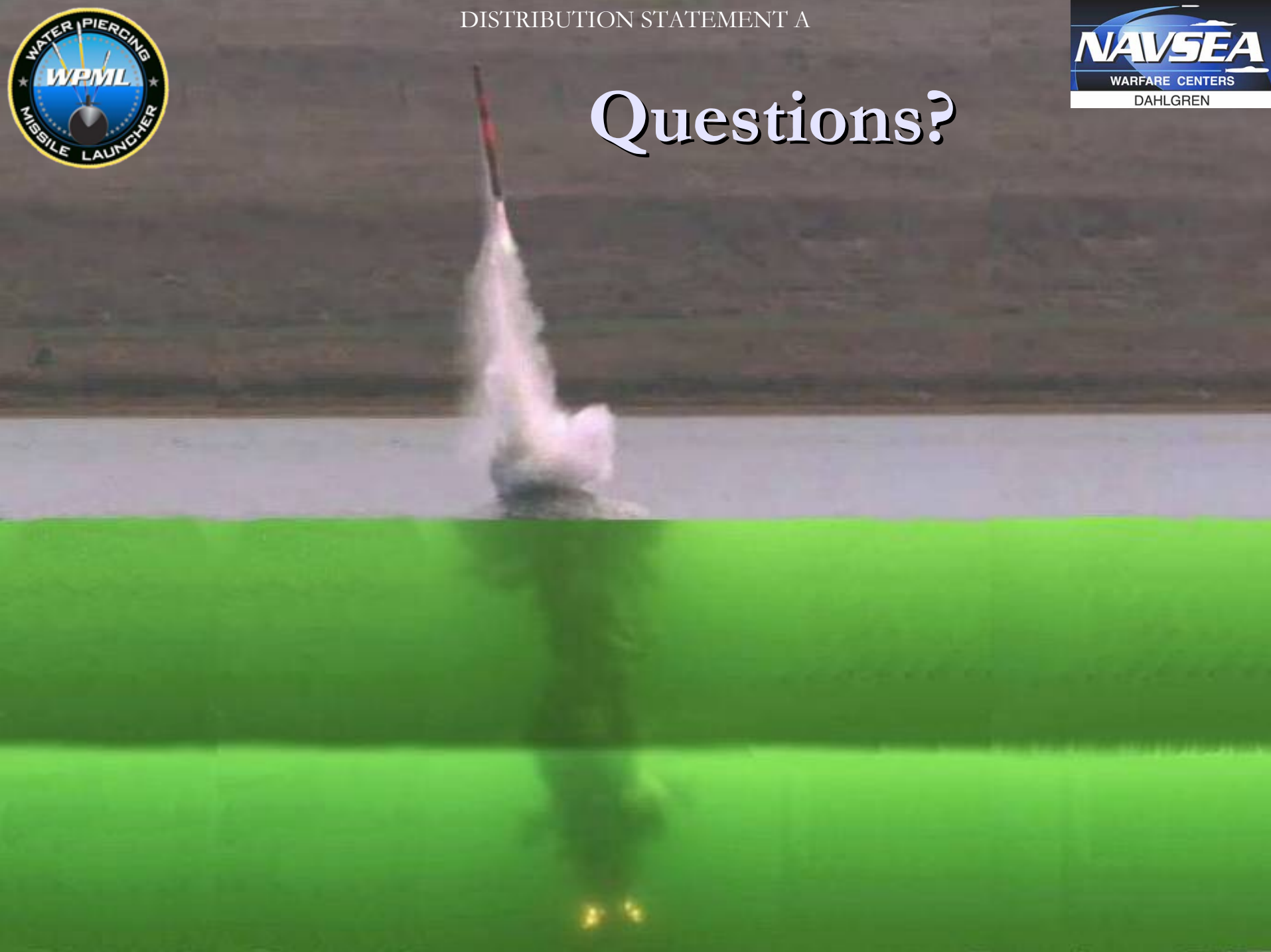
FY09 Work & Beyond

- FY09 tasks funded and moving forward
  - Attempt to instrument restrained shots
  - Port design into Sidewinder missile (ETF-SWR)
    - leverage legacy EE design
    - Integrate additional pressure & temperature sensors
      - Sensor requirements matrix currently being finalized
  - Develop on-board camera system to evaluate Sidewinder AIM-9X dome performance through egress
    - Camera down-selection currently underway
    - May incorporate telemetry, an on-board recorder, or both
    - Provides risk reduction prior to test with all-up AIM-9X
    - May provide additional insight into complex flow dynamics
  - Flight testing and data reduction for ETF-SWR and AIM-9X dome
- FY10+ possible tasking
  - Support at-sea flight testing with ETF-SWR
  - Instrument sub-scale models for laboratory testing

Credits

- WPML Sponsors
  - NAVSEA 073R (Undersea Technology Program Office)
  - PMS-450 (Virginia Class Program Office)
  - SSP (Strategic Systems Program)
- G64 (Integrated Weapons System Testing Branch) WPML Team
  - John Busic, Sam Koski, Dr. Jon Yagla
- G65 (Instrumentation Branch) Telemetry Support
  - Lin Conerly, Mike Weisman
- G33 (Precision and Advanced Systems Branch) ETF Team
  - Marc Bassett, Mike Irwin, Travis James, Nathan Joswiak, Hamish Malin

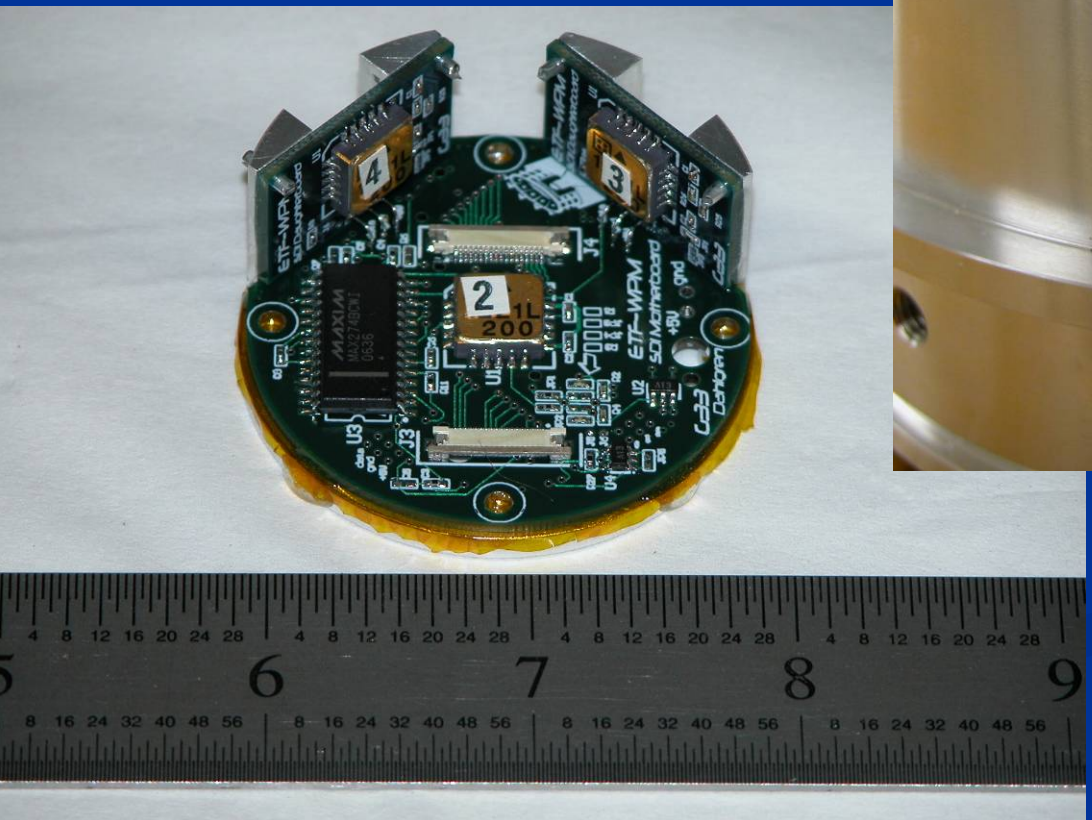
Questions?

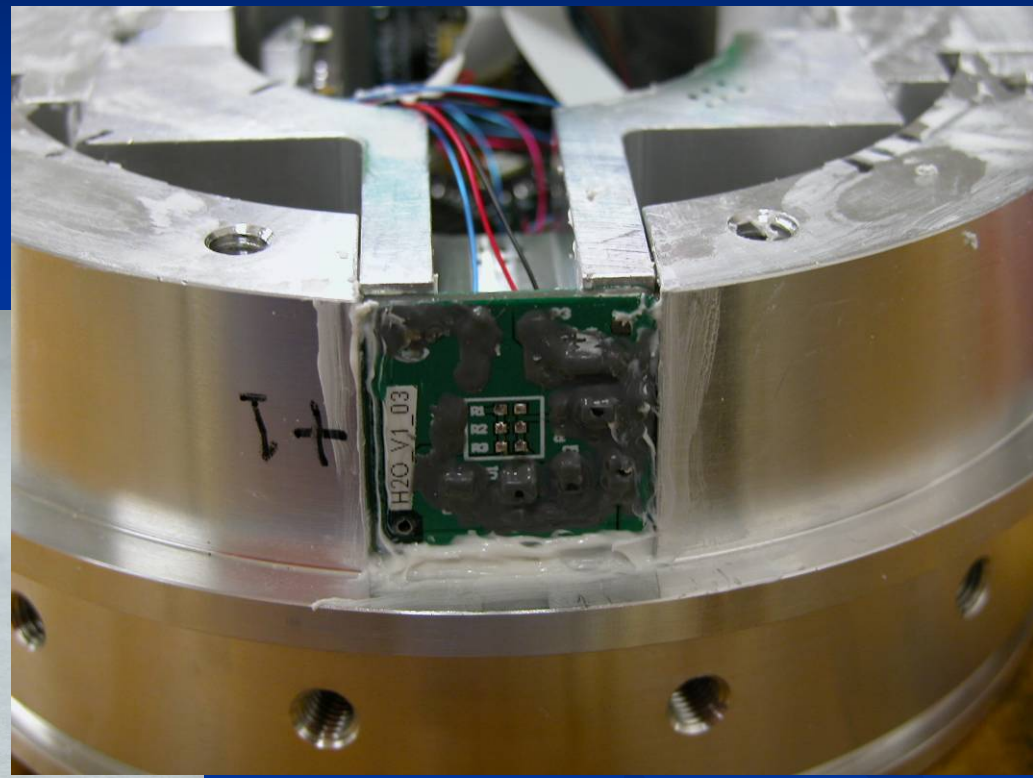


Backup Slides

Sensor Module details

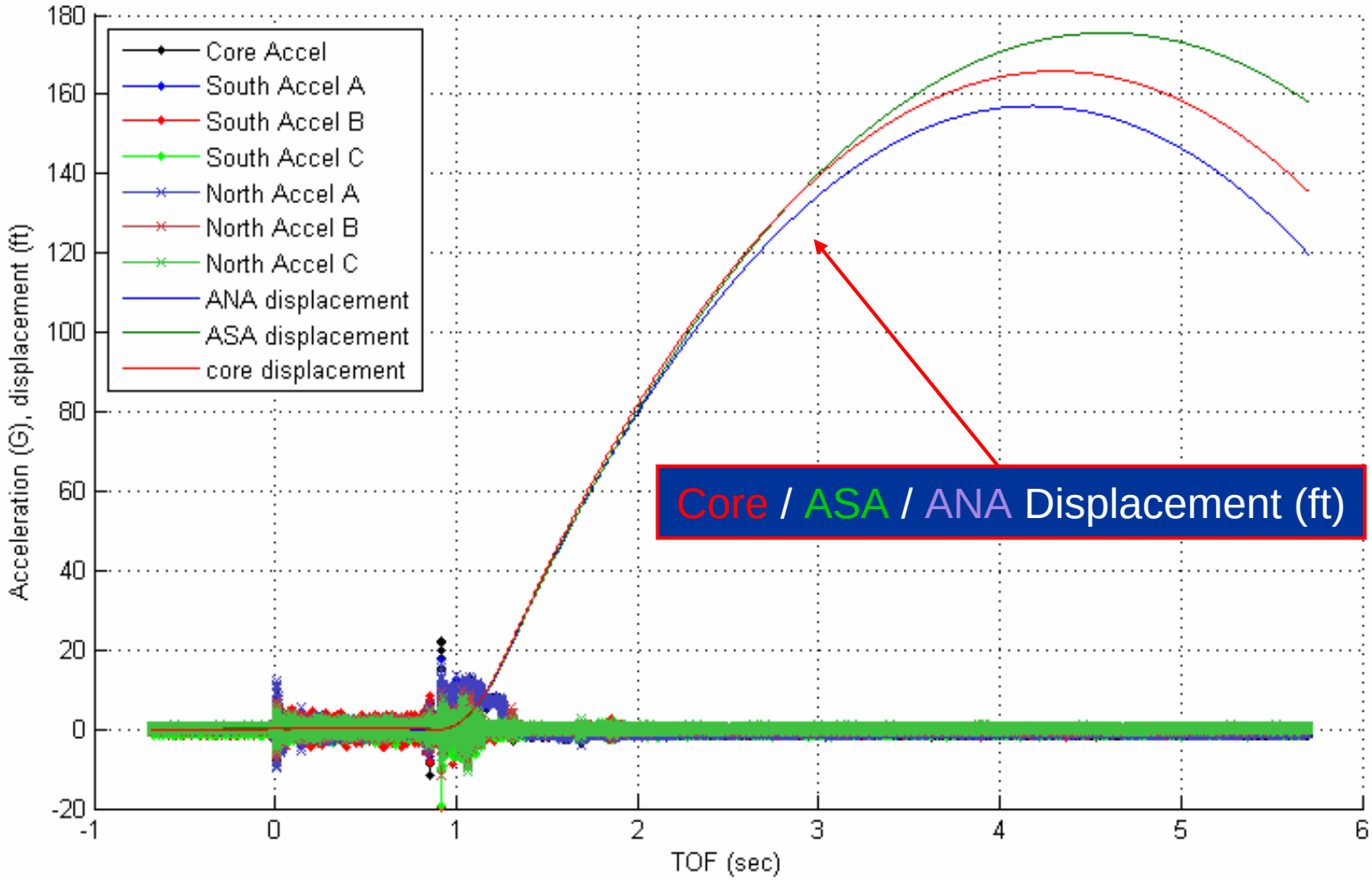
3-axis accelerometer module



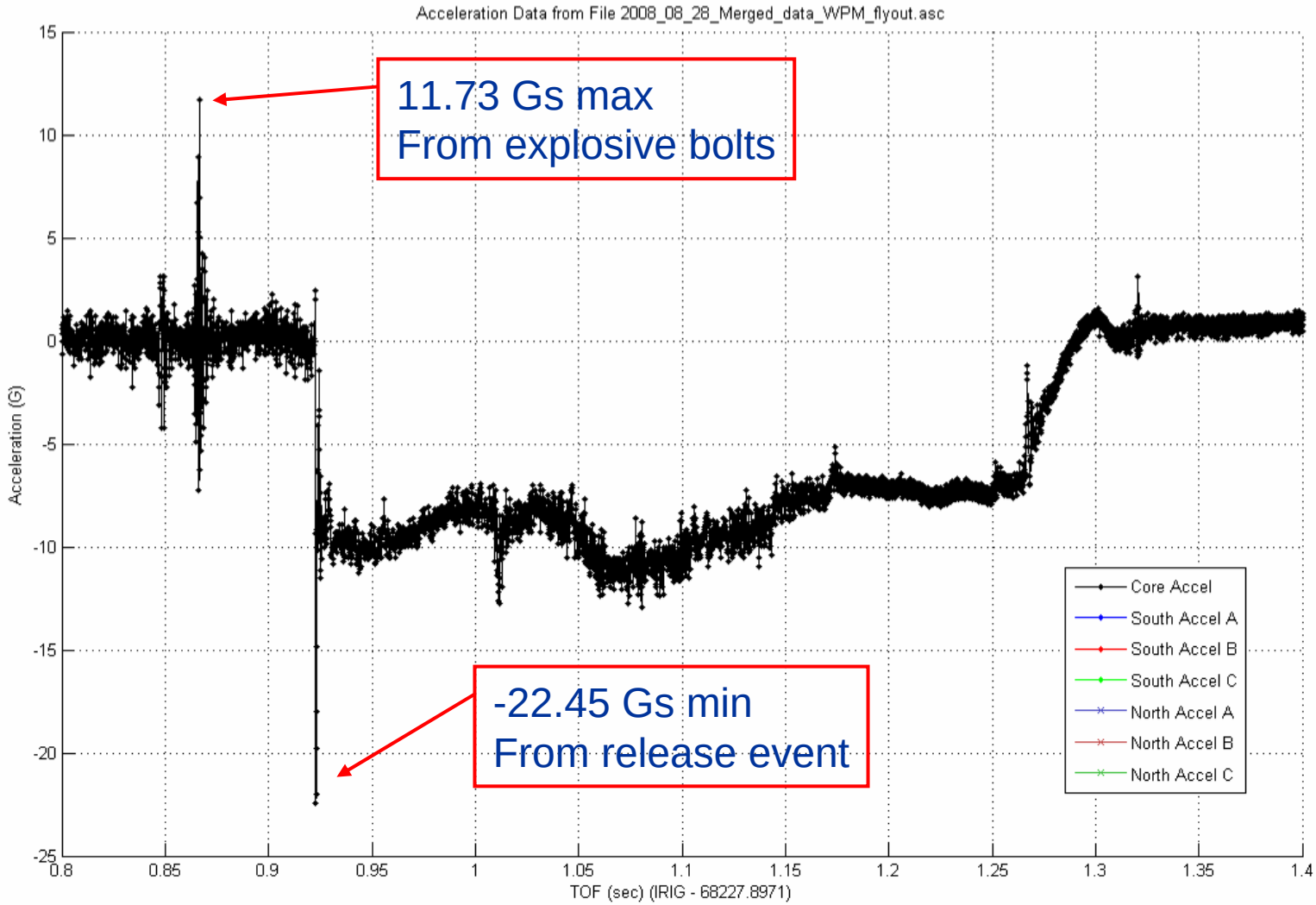


Surface moisture sensor

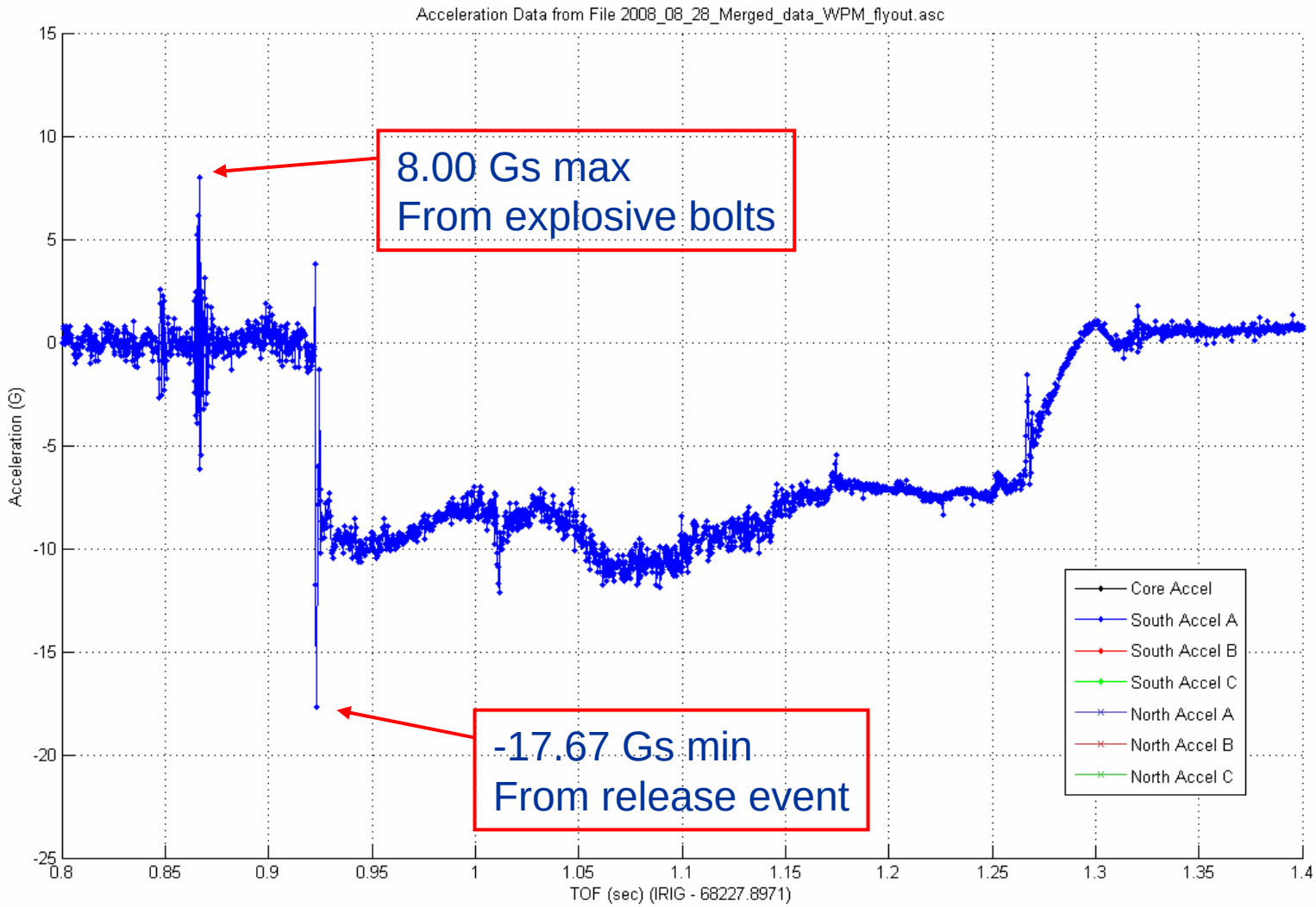
Axial Displacement



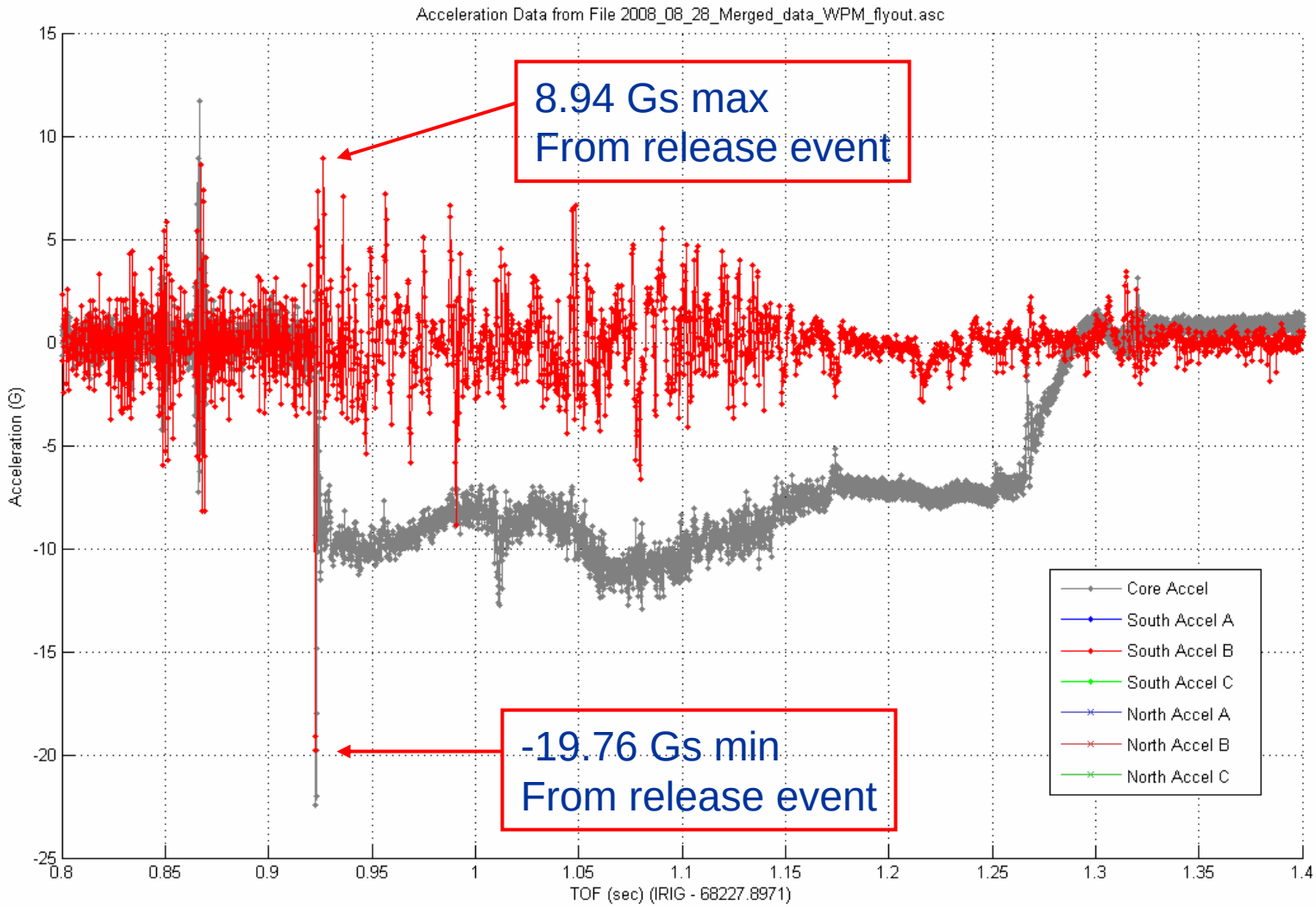
Core (axial) max/min



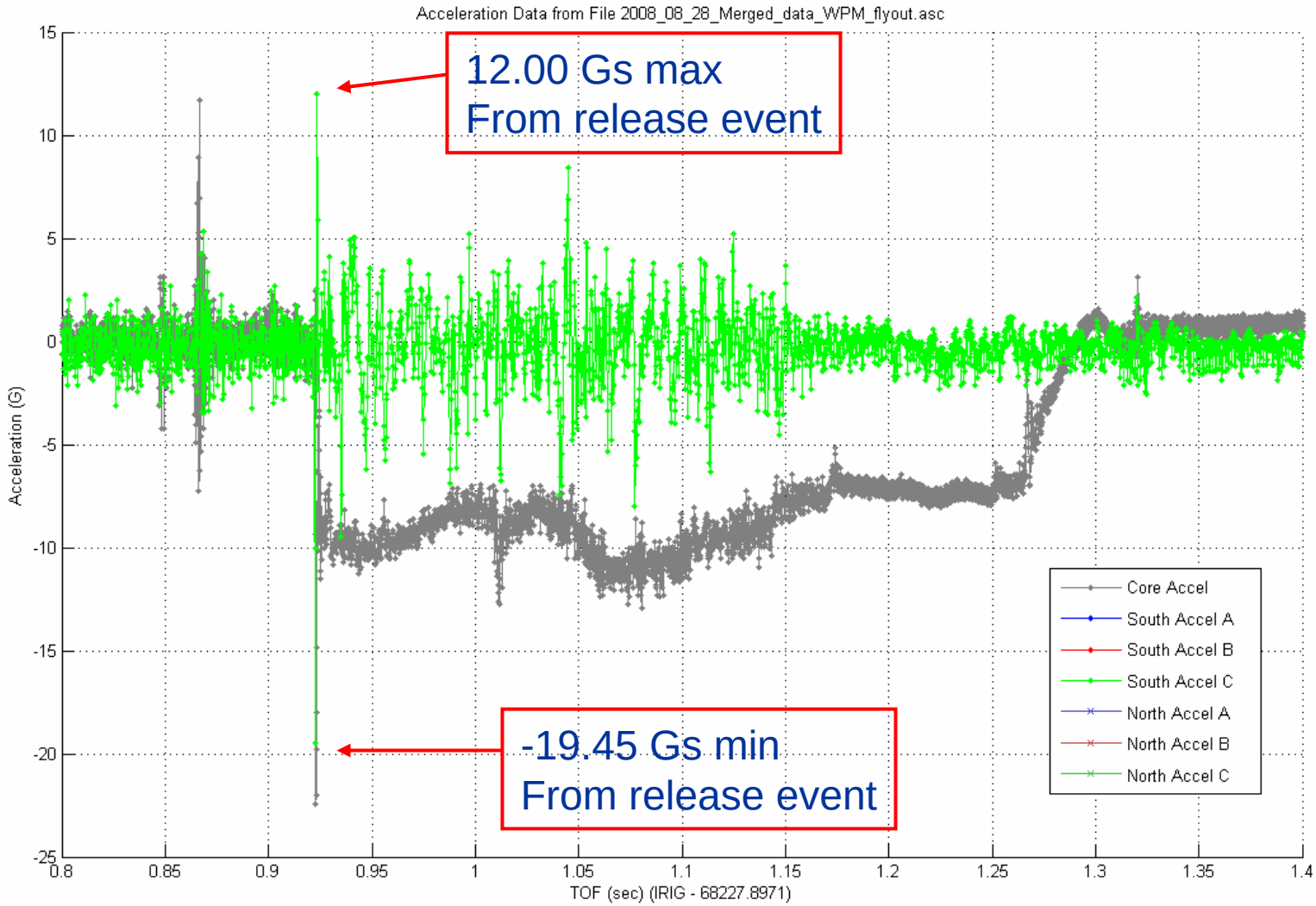
ASA (axial) max/min



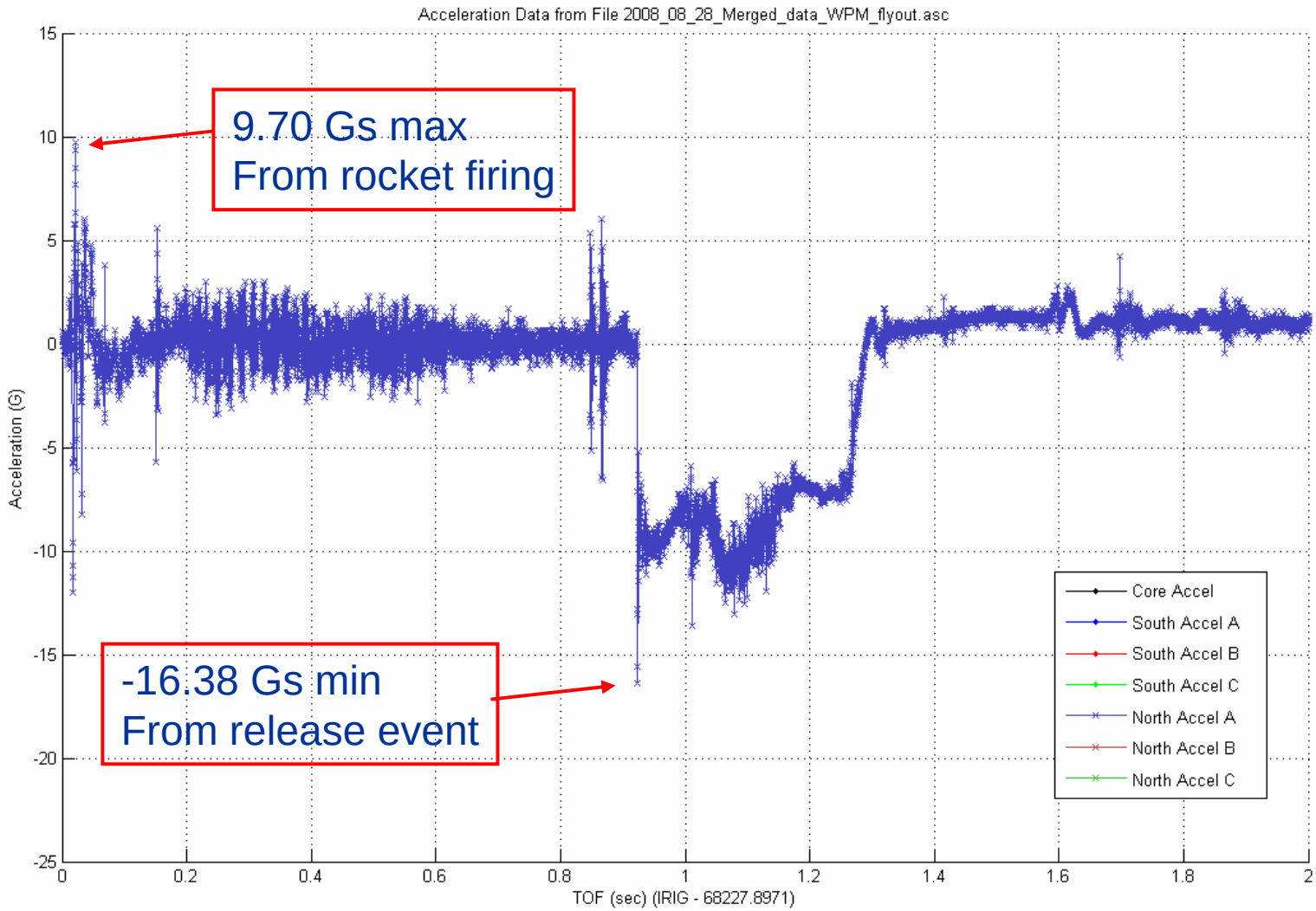
ASB (radial) max/min



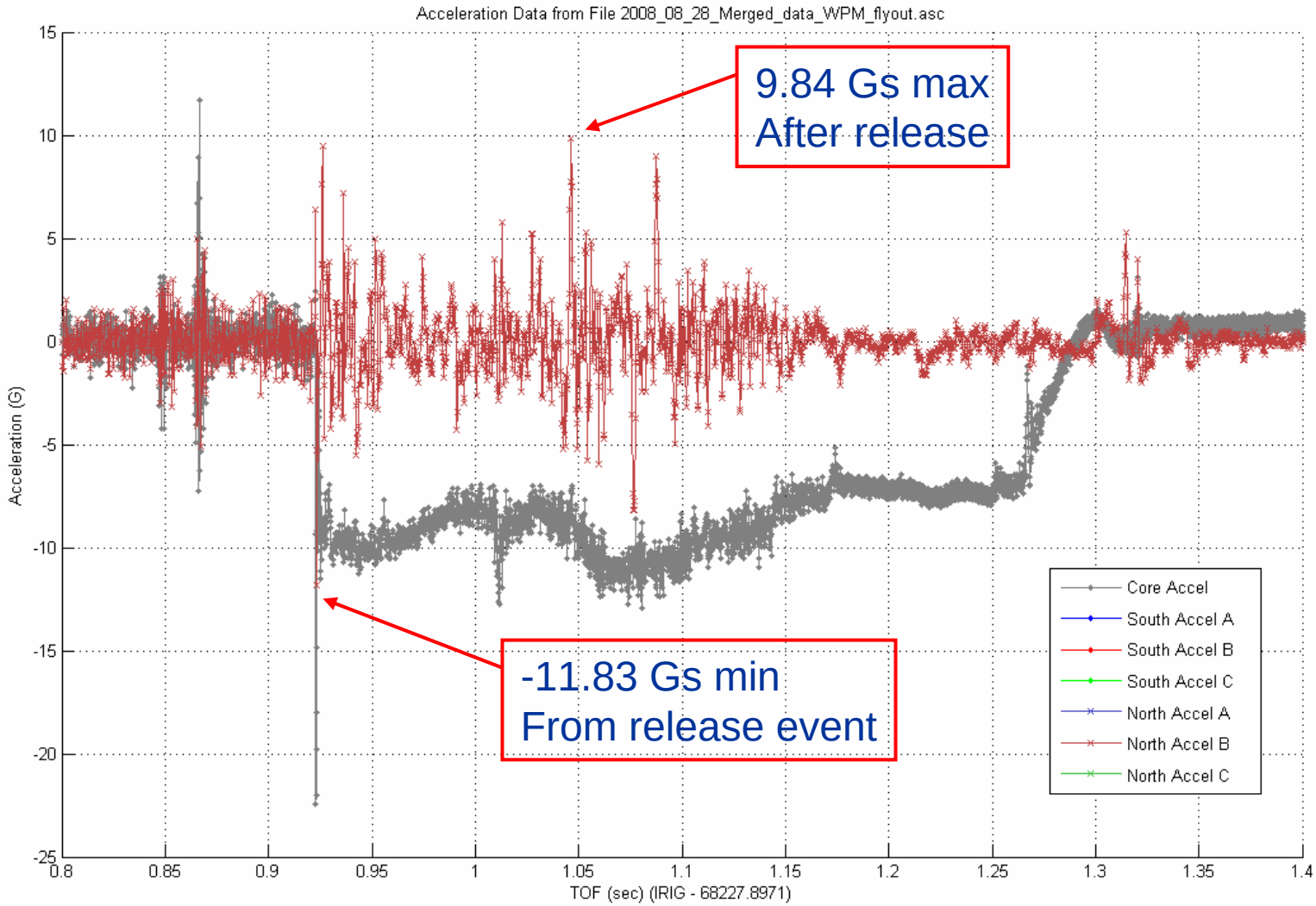
ASC (radial) max/min



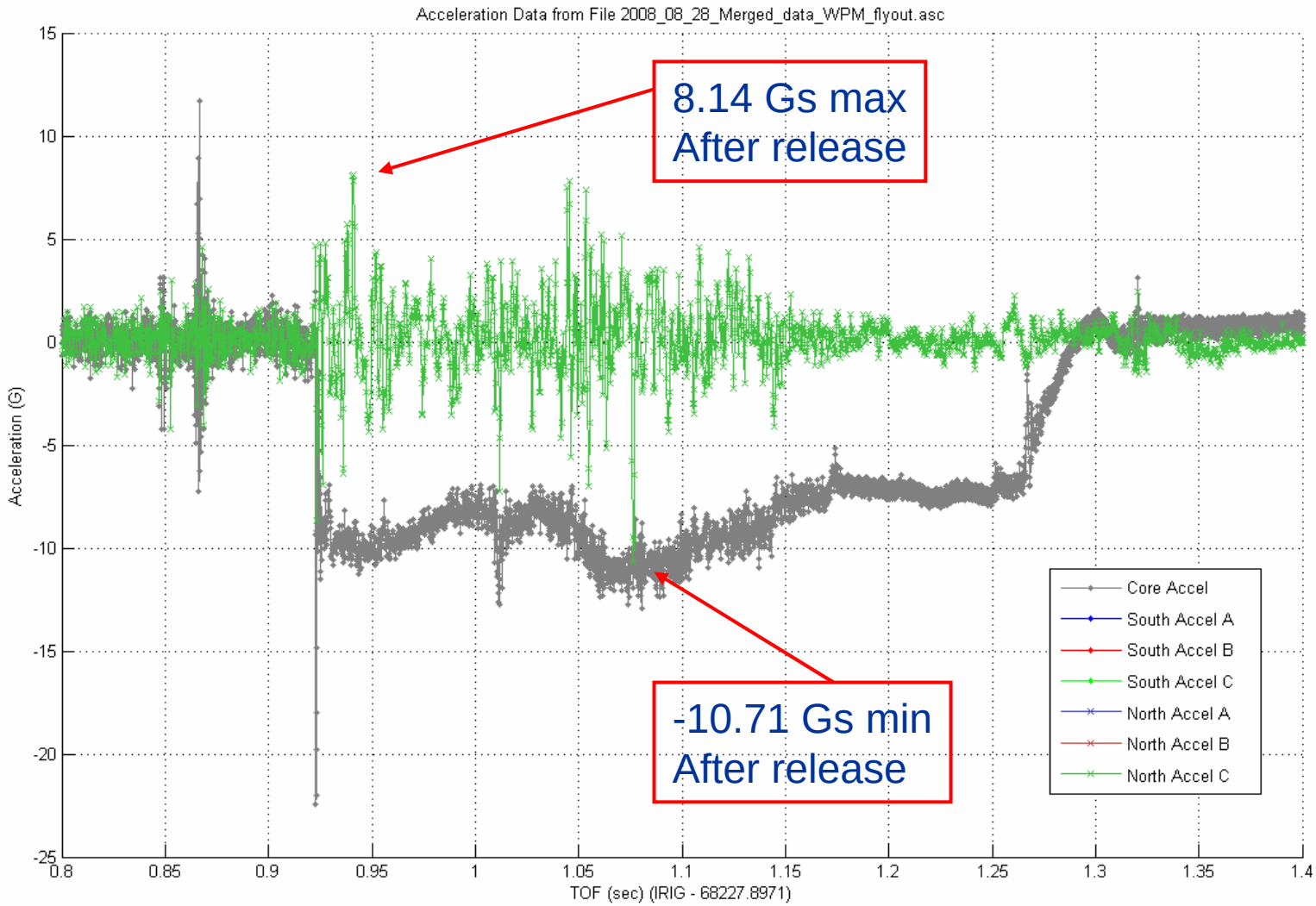
ANA (axial) max/min



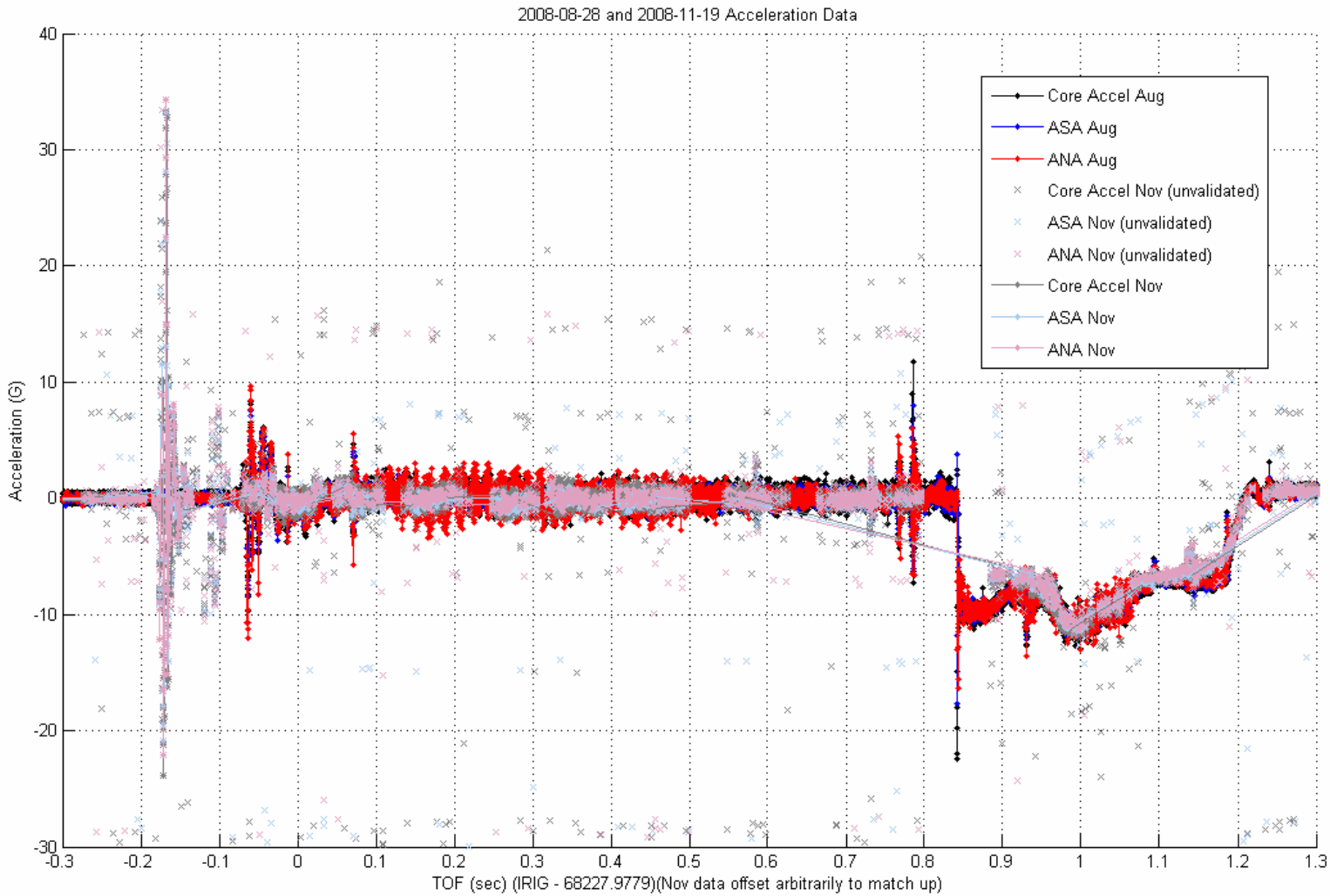
ANB (radial) max/min



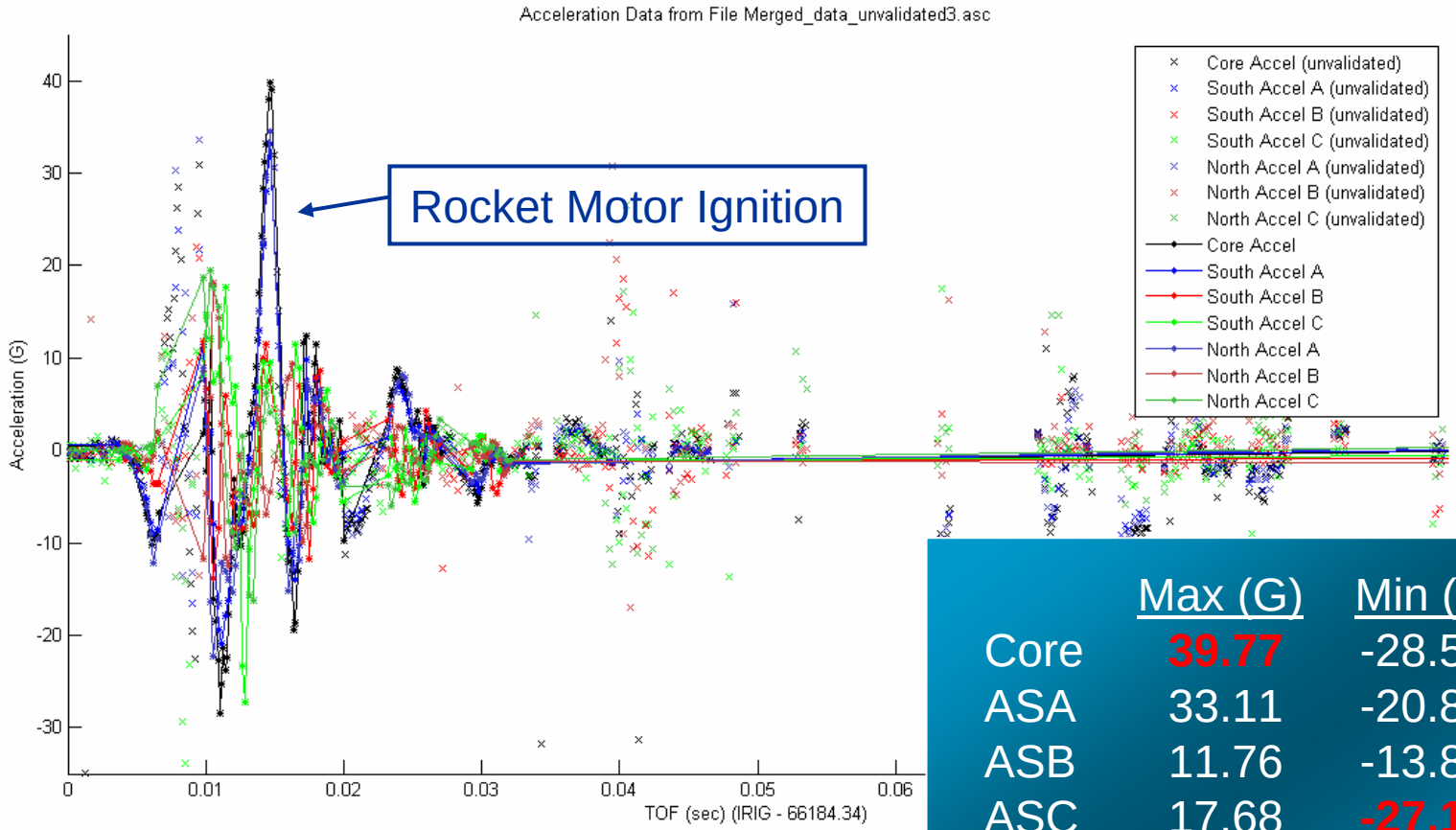
ANC (radial) max/min



Nov 19 2008 Data

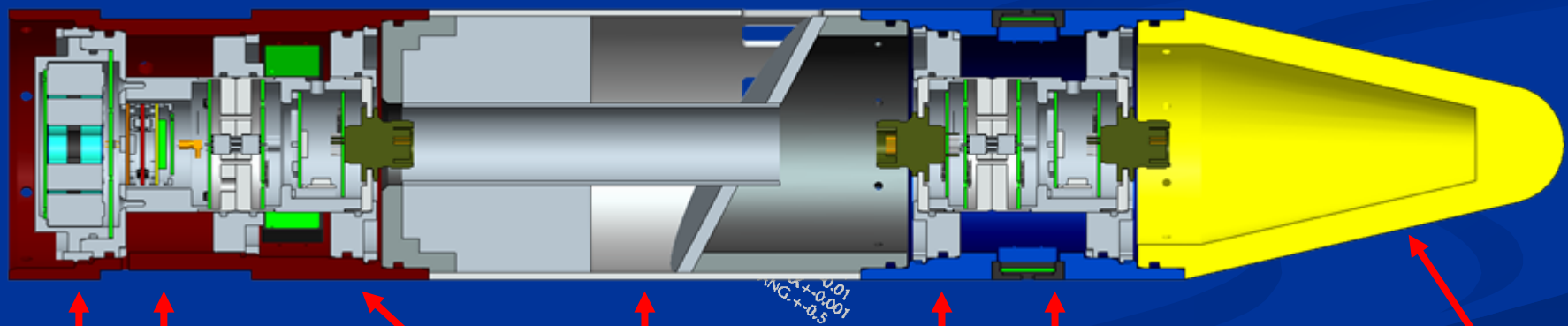


Nov 19 2008 Maxima



	Max (G)	Min (G)
Core	39.77	-28.50
ASA	33.11	-20.84
ASB	11.76	-13.87
ASC	17.68	-27.17
ANA	34.46	-22.22
ANB	18.13	-12.51
ANC	19.42	-16.31

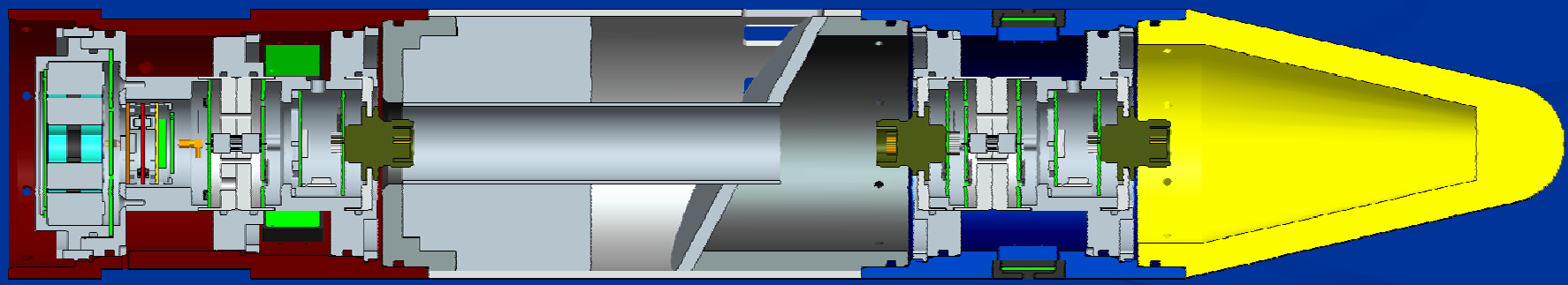
ETF-SWR Overview



ETF-SWR

Instrumentation Section

- Electronic design ported from FY08 JATO work
- Additional sensors (temperature/pressure) to be added into future nose section



Release Mechanisms

- Various release mechanism designs are being explored
- Three top candidates currently exist
- Final selection to be based on cost, performance, and risk