The TMAC Story

Maturing New Fast-Mover Instrumentation Through its Own Mission Capabilities

Rockwell Collins

Testing the Capabilities of the *Test* System

- Problem: Developing and TESTING a new system which is
  - More accurate
  - More throughput
  - Multi-platform
  - *Itself an instrumentation system*

- Solution:
  - Start early
  - Make a modular/upgradable reference plate that tests at a corresponding level of integration
  - Test against multiple/redundant independent truth sources
  - Staff the effort with a small full-time core team and embed developers from all relevant domains
  - Add “free” system testing by applying inherent system capabilities during test missions

The Test Situation – Specs so precise there's nothing to test against

- Uncharted territory early-on
  - No single Time-Space-Position-Information (TSPI) platform available to both fit *and* verify performance of the new precision system
  - Solution: built an Instrumentation Plate with multiple reference solutions and multiple prototype TSPI units

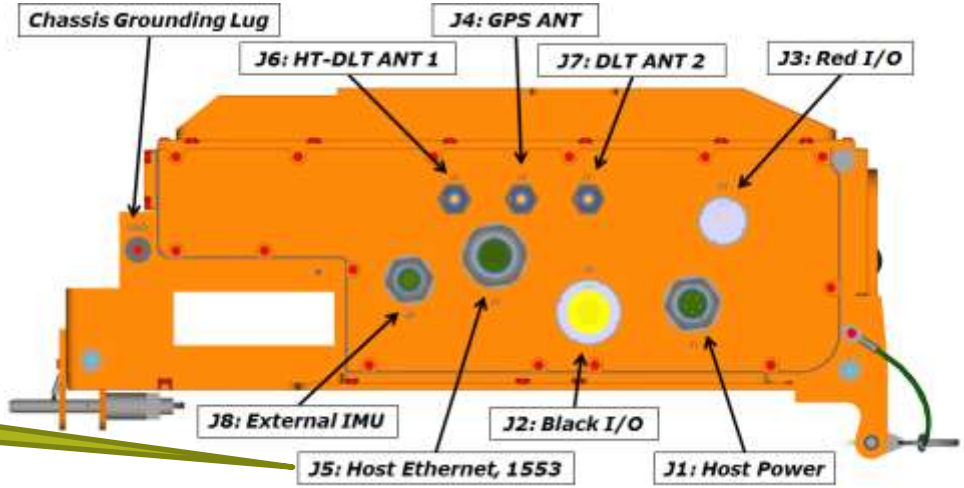
- Full-scale development
  - Needed fresh start on the plate – geometries, IMU noise reductions, recording bandwidth and robustness, real-time uplinks, downlinks
  - Must collect, manage, record, both "production data" and "debug"
    - Automatically, Manually, Locally, Remotely
  - Must have the plate as "one thing you could trust at every stage"
    - Same plate to fly on a fighter jet after "flying" on a bench or van

TMAC Key Lessons and Advances

- High accuracy plate is now a fully-characterized reference system for other projects
  - The plate proved success in fulfilling test system accuracy

- UUT's "Spare" ethernet port went from "nice" to "essential"
  - UDP/IP port remotely managed TMAC reference system in real-time
  - Wrung out and ready for remote management of customer instruments

- TMAC mission tempos "independently" matured the whole system
  - *Two-pronged, mission-oriented maturation beats "by the book"*

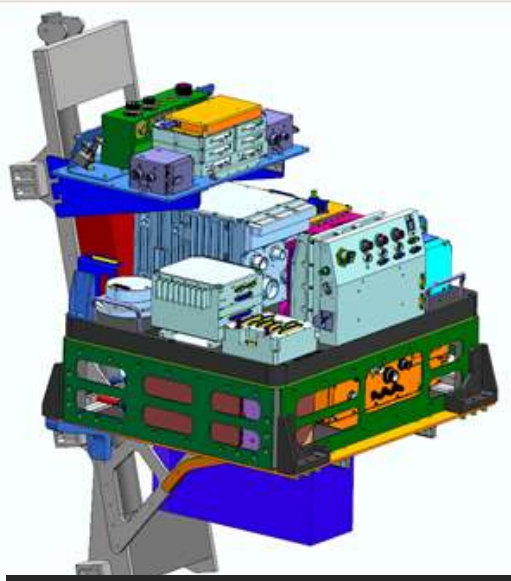


Secure "spare" UDP/IP Port came to life.

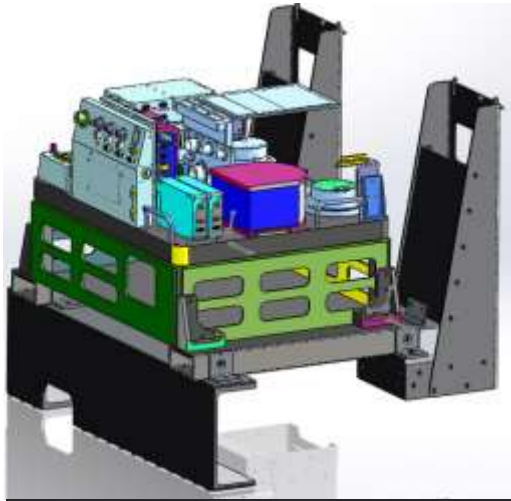
What's a TMAC?

- TSPI reference, plus unit-under-test plate (176 lbs in two halves)
  - Multiple precision reference systems
- Detachable bulk recorder suite (35 lbs)
- Co-locates 6 GPS, 6 IMU, 4+ Recorders, 1 Multi-function CPU in 24" x 20" footprint
  - A bit modular

- Objective: reduce TSPI development and integration and test costs
- Result: matured entire ground and airborne system
  - Easier now for range testers to securely collect or exchange their own 1553, ethernet, fibre, and 20 cm TSPI



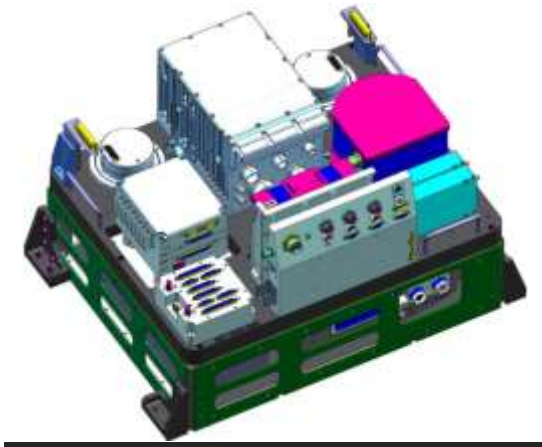
Trainer Back-Seat Replacement



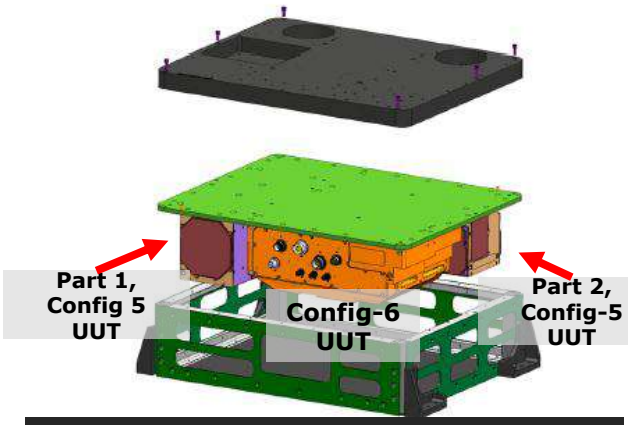
TMAC F-15 Mounting Configuration

What's TMAC do?

- Minimize sorties by flying multiple LRUs vs. truth
  - And test vs. each other
  - Leverage low-cost flight hours early to minimize Eglin sorties
- Test continuity through entire development from module to flight
  - Continual known, trusted environment; small-steps vs. big bang
- Environmental / SOF qualified
  - Aboard T-38, L-29, F-15, F/A-18, Chevy commercial van
- Levels of test rigor prior to flight
  - Spirent-tested vs. GPS lab environment
  - DLT emulator to bring dynamic network robustness
  - KVM access to quickly/locally manage the package during manned flight
- Multiple data links over course of development
  - 3G cell datacard link (early surrogate)
  - ARC-210 link (later surrogate)
  - QNT link (robust, spectrally inefficient for range use)
  - Hyper5000 (limited range)
  - HTDL (production, robust and spectrally efficient)



First flew only the top half



Added the Units Under Test below

Stepping Stones of Integration

Module lvl intg: A/C Intfc, Crypto, GPS, Datalink

Prop Env Tests

Mass Mockups

Gnd Sys Checks

Separate Ref Plate tests: Record-only, temp datalink

Separate Datalink Plate tests, recording

Ref Plate + Datalink Plate + Ground System

Ref Plate with 1-2 LRU Unit Under Test

Lab / Model / Virtual environment checkout

Module / Functional-level real-world testing

First-order combined real-world maturation

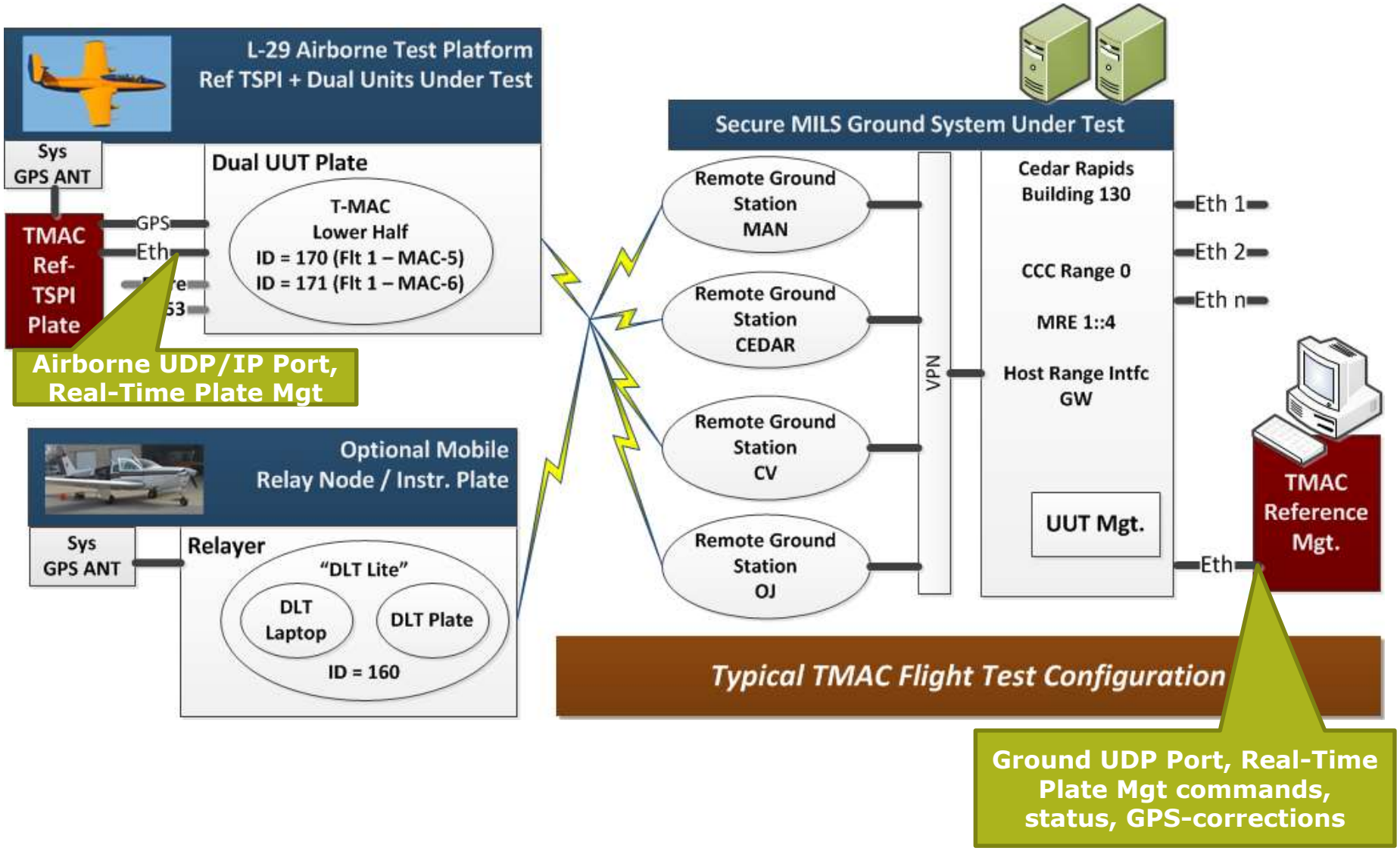
Secure, end-end system-level events

TMAC Reference Plate elements covered span of development-early proto stage through Qual Testing

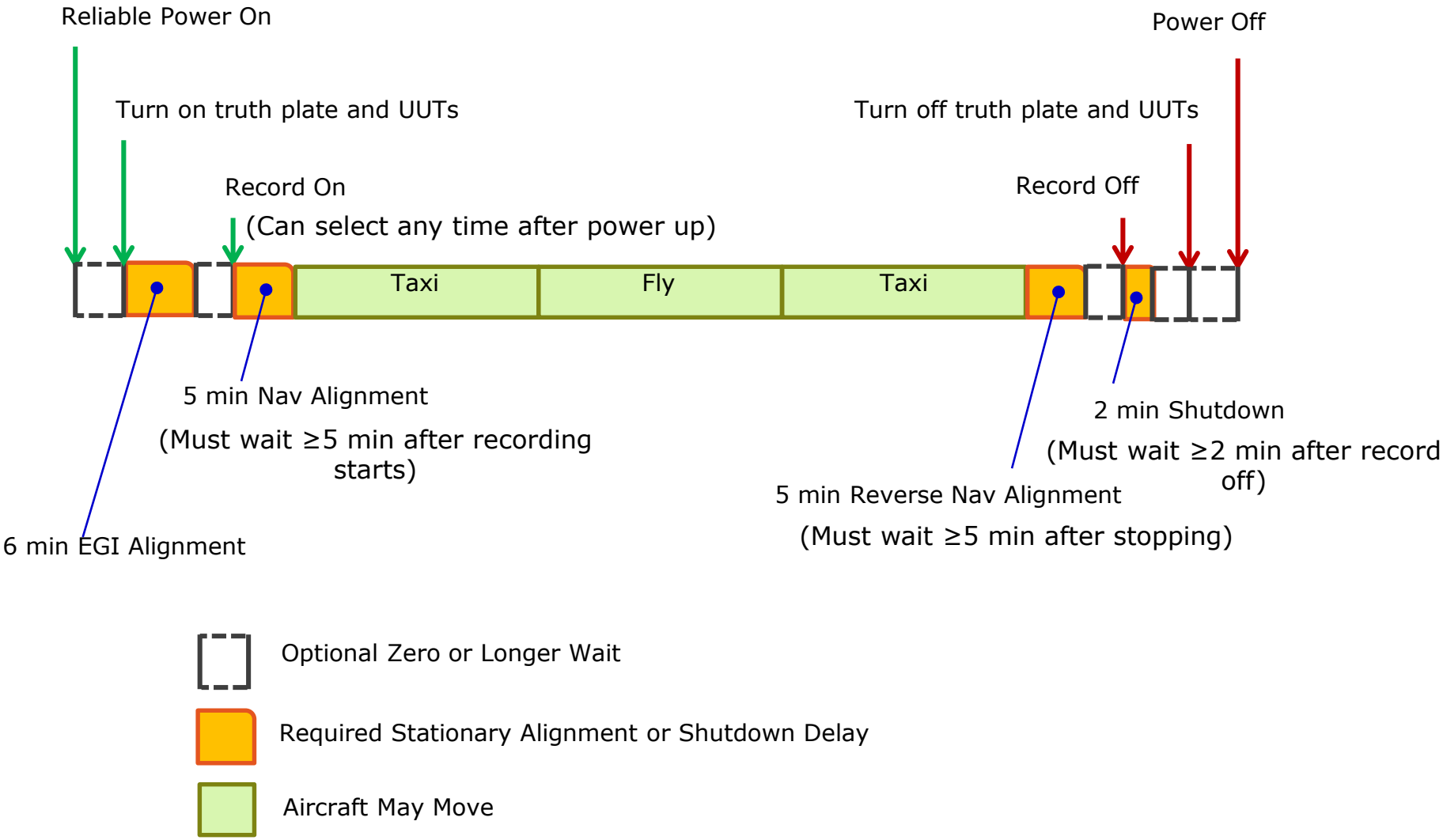
Lab and Van Integration Stages

- Dry runs sequences of complete missions on lab bench…
  - … Became going mobile and adding robustness in ground environment
- Learned
  - Daily remote ground station management
    - Sites, WAN, LAN ready for flight tests
  - IMU alignment on multiple platforms
  - Commercial GPS Reference Receiver obsolescence, reintegration
  - Antenna placement (GPS at high position)
  - GPS RTK corrections effective range
  - GDGPS corrections resilience
- Improved MILS handling over UDP port
- Improved datalink dynamic routing robustness in urban environment
- Confidence on the range

Range Flight System Network Topology



Flight Test Timeline



High Dynamic Maneuver Checklist

Maneuver	G Level	Airspeed (KCAS)	Altitude (ft MSL)	Est. Dur. (sec)	Rep
3-4 g figure 8	4g	250-280	5K-16k	60	1x
Split S	4g	120 - 300	5K – 25K	20	2x
Cuban 8	4.5+ g	100-300	5K-16k	60	2x
Immelman	4.5+ g	200-300	5K-16k	30	2x
360° Aileron Roll Left, ¼ stick	3.5+ g	200-250	5K-16k	20	3x
360° Aileron Roll Right, ½ stick	3.5+ g	200-250	5K-16k	20	3x
180 ° 5-6 g Turns	5+ g	200-300	5K-16k	20	As required

Eastern Iowa Test and Training Range Flights

- Disciplines gained in dry runs of all formal CT&E flights
  - Roughly 25 flight events
- Proved out Reference Receiver switching
- Proved out dynamic Kalman filter resets
- Proved out ultra-tight coupling in a precision SAASM receiver
- Customer Qual credit for successful GPS-Denied mode
  - Cfg 5 and 6 UUTs ran GPS-denied mode, while reference TSPI scored
- Demo'd ethernet UDP/IP connection from experimental OFP to ground system
- Added analysis tool improvements
- Real-time visualization through customer tools

Flight Lesson examples

- Lesson: GPS Integer fix corrected
- Lessons: datalink 2nd hop broadcast during flight testing
  - Discovered, made corrections for oversubscription of broadcast resources
- Lesson: Positive stress test for recording
  - Message by Message testing up through rated capacity in single payload
- Lesson: Type 1 and Type 3 encryption integration

Single Cfg-6 Node on Relayer

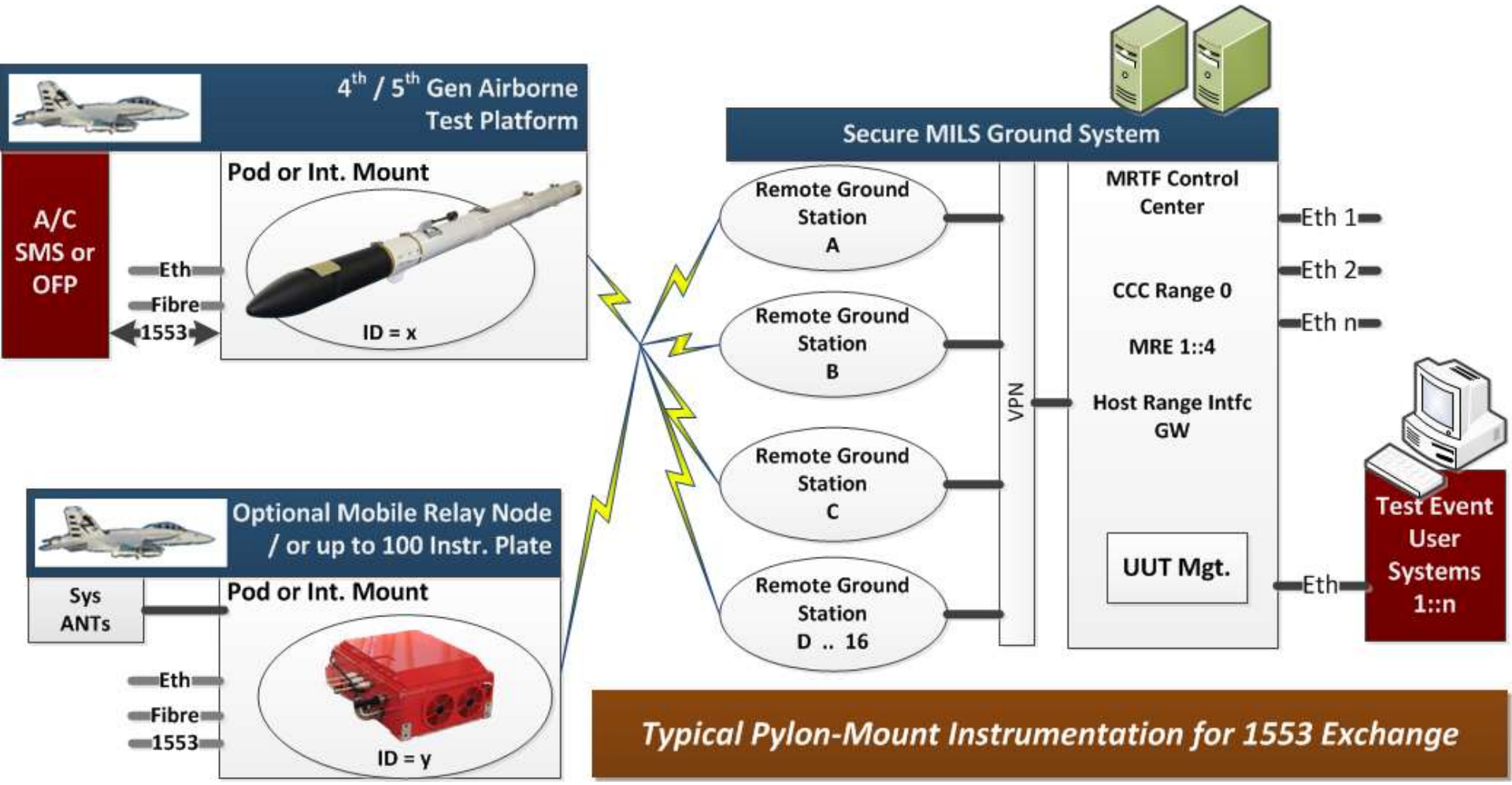
TMAC fitted into aft seat position

All-Season Testing

Next Steps:
Contractor Test and Evaluation Flights
Government T&E Flights

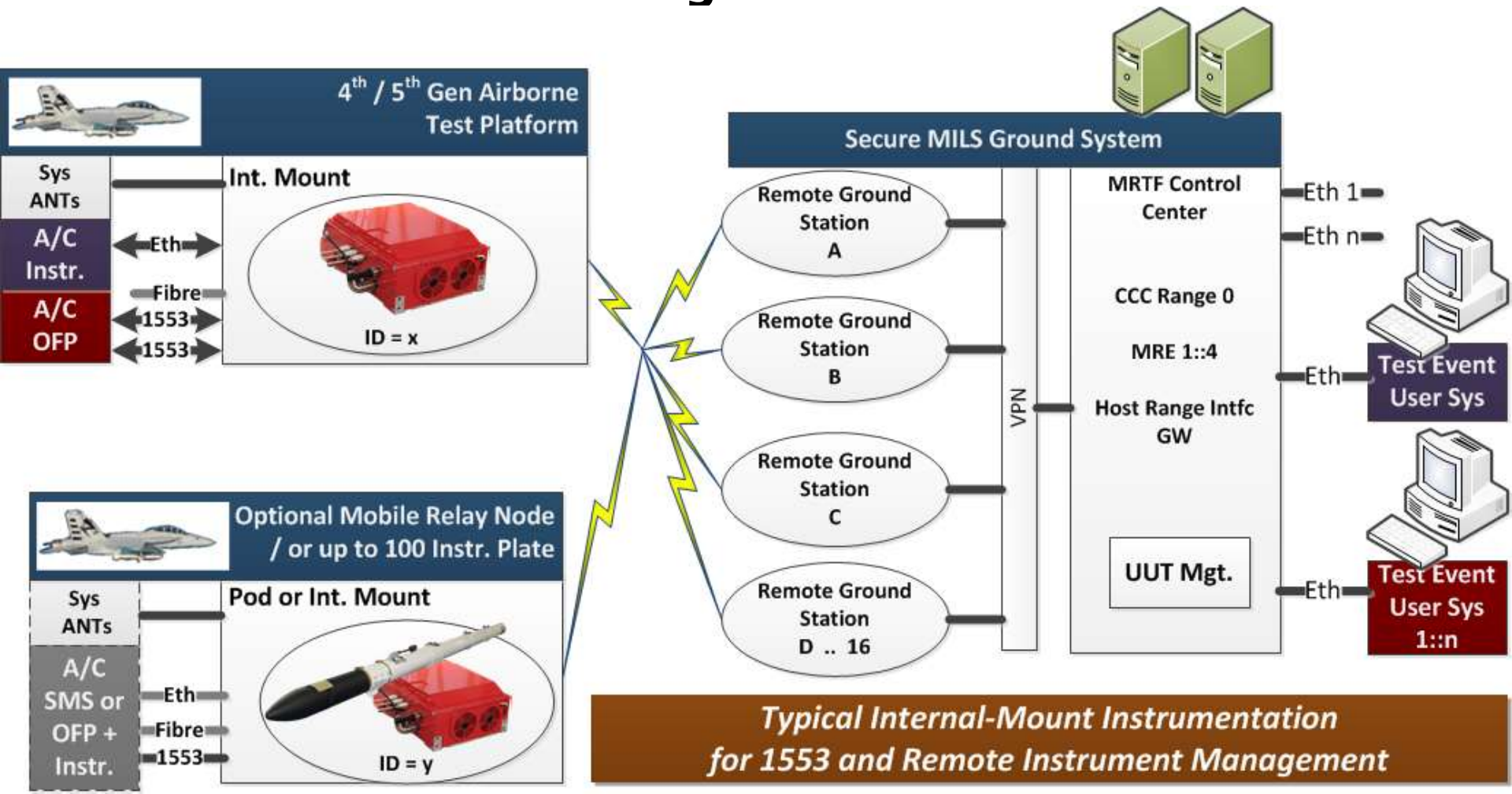
- Precision, two-layer, 170 pound plate safely fitted and integrated into F-15 aft cockpit bay
  - All reference units, plus dual LRUs under test
- Orange-wire cabling integrated
- Dual system antennas integrated (2 Instrument plates qual'd per flight)
- Onboard liquid chiller fitted aboard F-15
- F-15 Eagle EMI compatibility completed
- Aircraft stationary tests, ground checks completed
- System is ready; awaiting A/C return from servicing

Sample Application: 1553 Exchange



Typical Pylon-Mount Instrumentation for 1553 Exchange

Sample Application: Remote Instrument and Dual 1553 Exchange



Typical Internal-Mount Instrumentation for 1553 and Remote Instrument Management

What's been gained through TMAC?

- Ops Tempo: Multiple packages and multiple sorties daily
- Each stage of a DT/OT mission wrung out at home
  - Planning, replanning
  - Pre-flight
  - Restarts during pre-flight, taxi, in-flight
  - Recovery from operator errors
  - Post-mission analysis

- Maturation through mission-oriented flight operations
  - Matured precision TSPI functions
  - Application-oriented use of user-configured UDP/IP interface
    - Complements 1553, Fibre interface integration at DoD, Airframe SILS
    - Successful remote management of precision reference instrument
  - Matured MILS environment, Type 1 and Type 3 encryption
  - Matured robust networking with 5x ARDS capacity