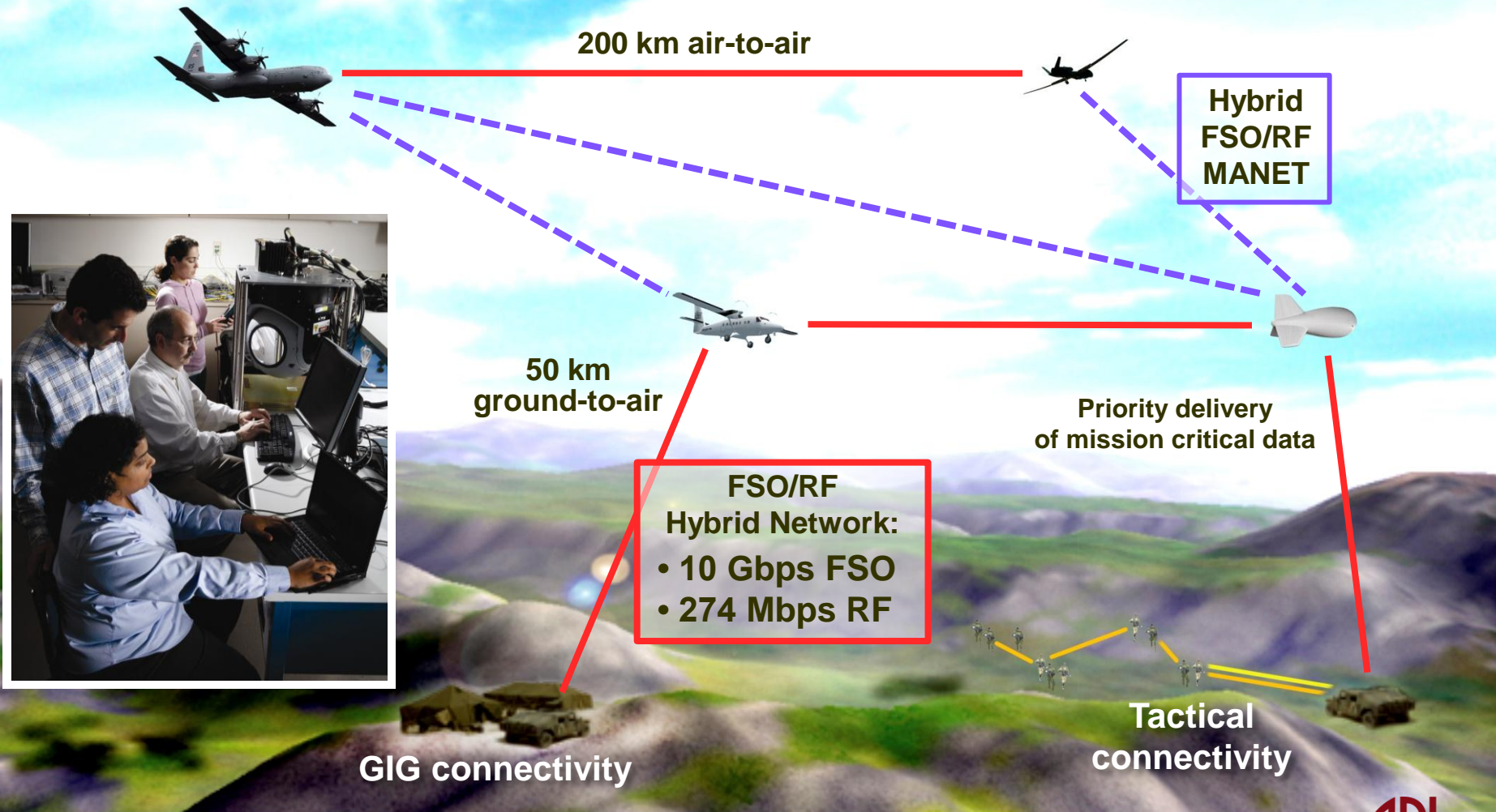


Hybrid RF Network & Free Space Optical Communications

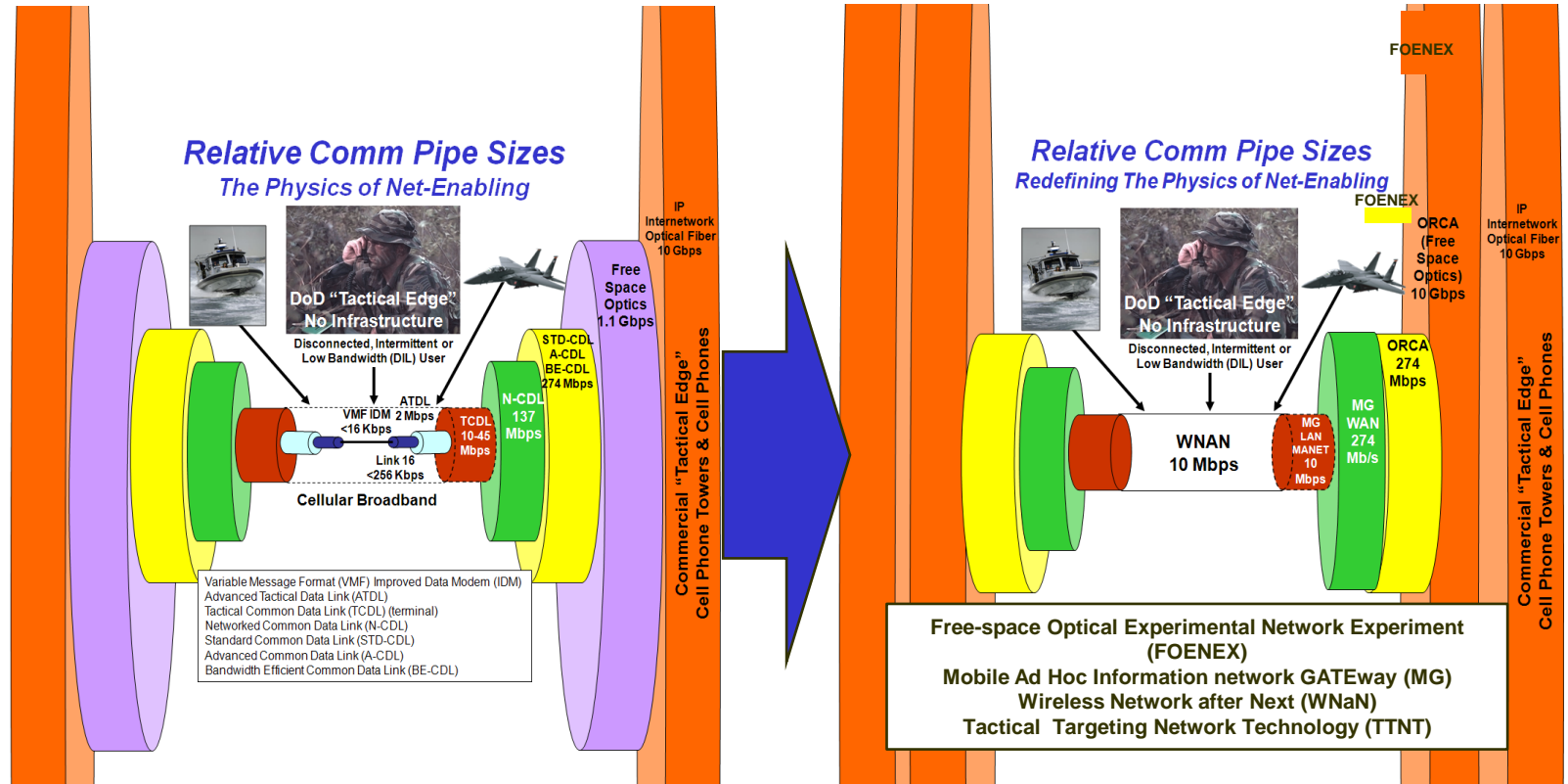
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APPLIED PHYSICS LABORATORY

Free Space Optical Communications Network

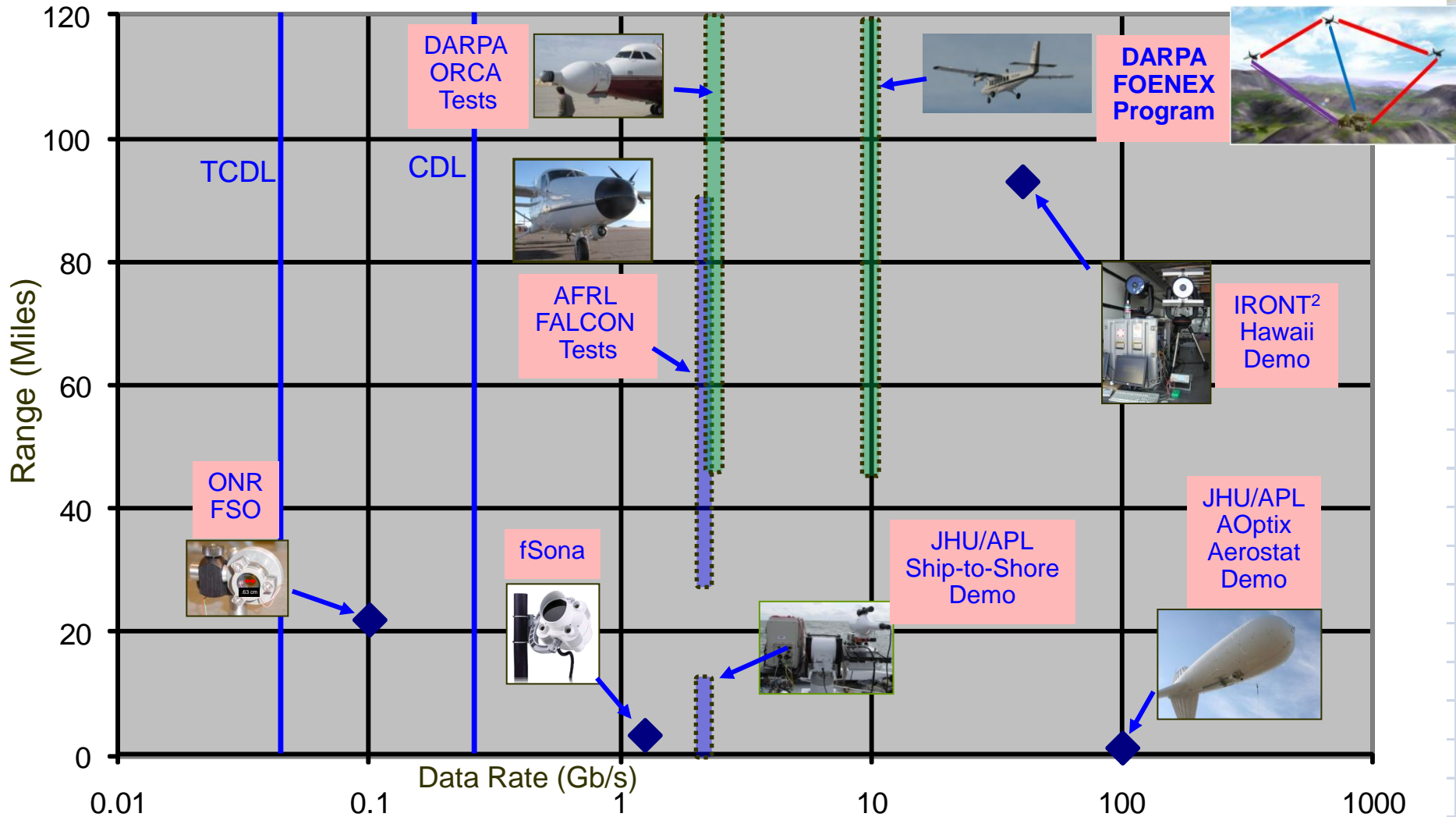


Why 10Gbps Free Space Network?



**Providing Higher Data Rate ISR Dissemination to the Tactical Edge:
Interoperable and Integrated**

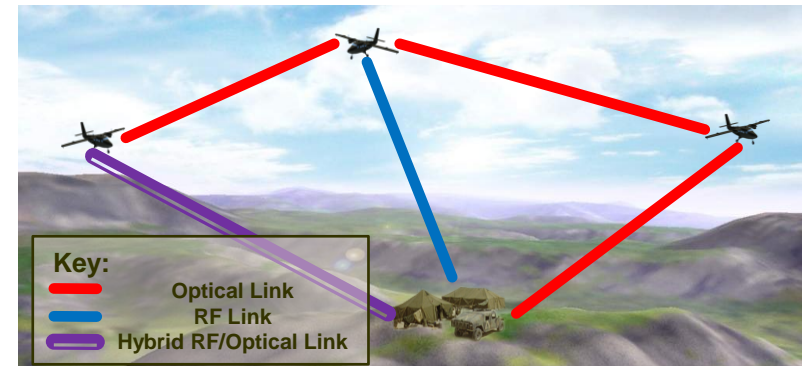
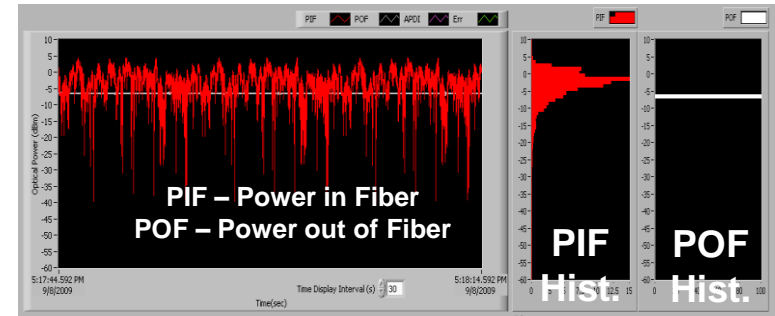
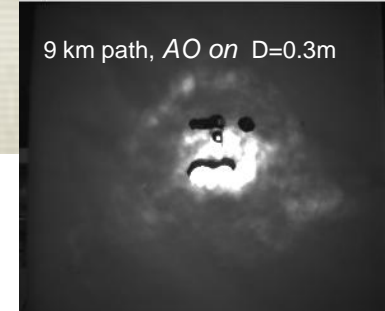
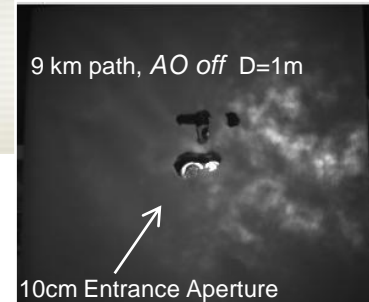
Advances in FSOC Link Distance Enable Hybrid FSO/RF Network



FSO Technical Challenges

What has prevented the Development Community From Reliable FSO?

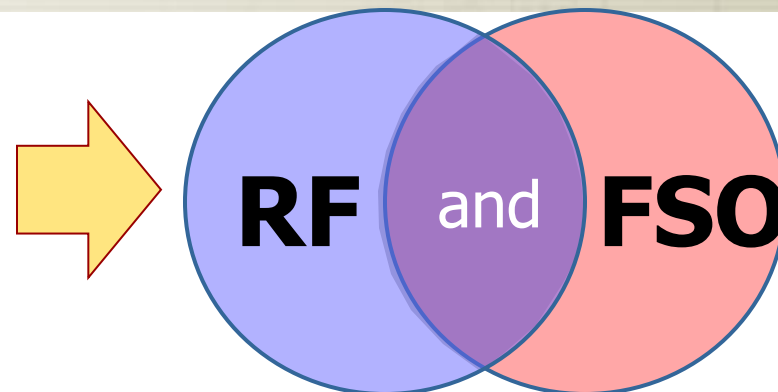
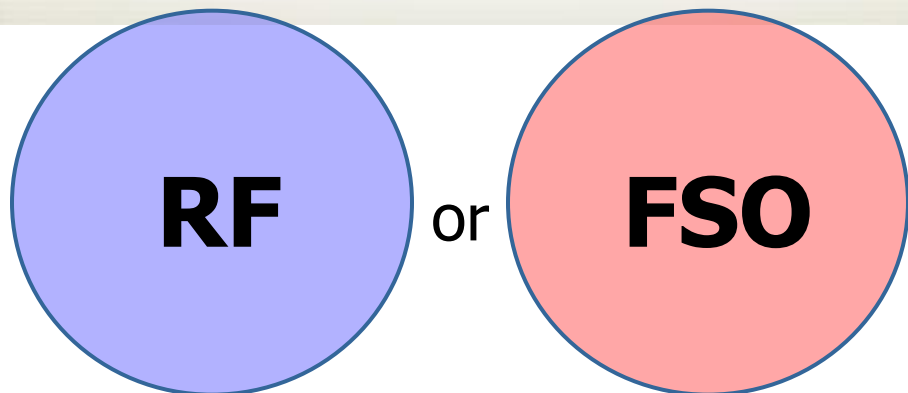
Tech Challenge	Solution	Maturity/Risk
Laser beam wavefront distortion	Adaptive Optics (AO)	Well developed (AOptix)
High dynamic range of received optical signal	Forward Error Correction w/Optical Automatic Gain Control	Well Developed (JHU/APL)
Pointing Acquisition and Tracking (PAT) @ 200 km	IR Beacon Acquisiton & handover to (AO)	50km demonstrated to date (AOptix)
Data Loss (clouds, blockage, deep fades)	Hybrid FSO/RF	Well developed (ORCA & Iron T2 baseline)
	Retransmission	New for FOENEX
	Link Diversity	New for FOENEX



Technical Approach Paradigm Shift: Hybrid Optical-RF Communications Systems

Stand alone approach to comms links

Hybrid Approach to Mobile Free Space Communications
with High Availability and High Average Data Rate



RF

- Low Data Rate
- Stable Channel
- Relatively immune to cloud blocking
- Sometime affected by rain

FSO

- High Data Rate
- Bursty Channel
- Must have clear / haze conditions
- Less degradation than RF in Rain

Generally complementary channel characteristics

- Enables Free Space Optical (FSO) Communications bandwidth without giving up RF reliability and “adverse-weather” performance
- Improves network availability Quality of Service (QoS)
 - More options for adapting to weather
 - Common atmospheric path effects and compensation (directional links)
 - Physical Layer diversity improves Jam Resistance
 - Size, Weight and Power (SWaP) Focus
 - Leverages common Power, Stabilization, etc.
 - Economical use of platform volume
- Enables seamless transition of free space optical communications into RF Environment

FOENEX Program Objectives

Dynamic Node Discovery, Inter-Platform Communication Manager, IPCM Adaption Layer, mobility management, and QoS network control enable the FOENEX MANET

Air-to-Air Cross-links
FSO/RF TRL 6 Prototype
> 200 km Node Separation
≥ 95% Availability @ 10 Gb/s data rate
≥ 95% Availability @ ≥ 112 Mb/s info rate

Air-to Ground / Ground-to-Air Links
FSO/RF TRL 6 Prototype
Adverse Weather
Up to 50 km Slant Range
≥ 60% Availability @ 10 Gb/s data rate
≥ 95% Availability @ ≥ 185 Mb/s info rate

GIG / Fiber Optic Point of Presence

Goals:

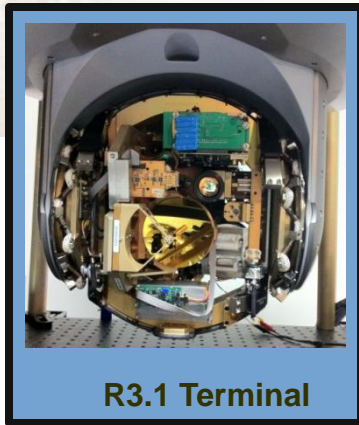
1. Provide dispersed warfighters a GIG connected tactical network communications backbone
2. Enable FSO bandwidth comms w/RF network availability
3. Enable reliable, on the move, at the halt and airborne communications

Technical Challenges:

1. Acquisition, Pointing and Tracking of hybrid communications terminal from air to air and air to ground
2. Extremely high network availability
3. Real time transition between FSO and RF operation

Develop & Demonstrate a Leave-Behind, High Reliability, High Date Rate Comms System

Overview – Free Space Optical (FSO) Terminals



FSO Terminals Functions:

- **R3.1 FSO** terminal payload for air and ground terminals
 - Operated at 30kft
 - Ground outdoor enclosure IP-65 rated
- **Air Terminals** use mounted MX-15i skyball pointing turrets
- **Ground Terminals** use Cobham Defense SPS-500 pointing gimbal mounted via tripod
- **External PAT electronics chassis**, housed in rugged transport case, is used by both Air and Ground terminals

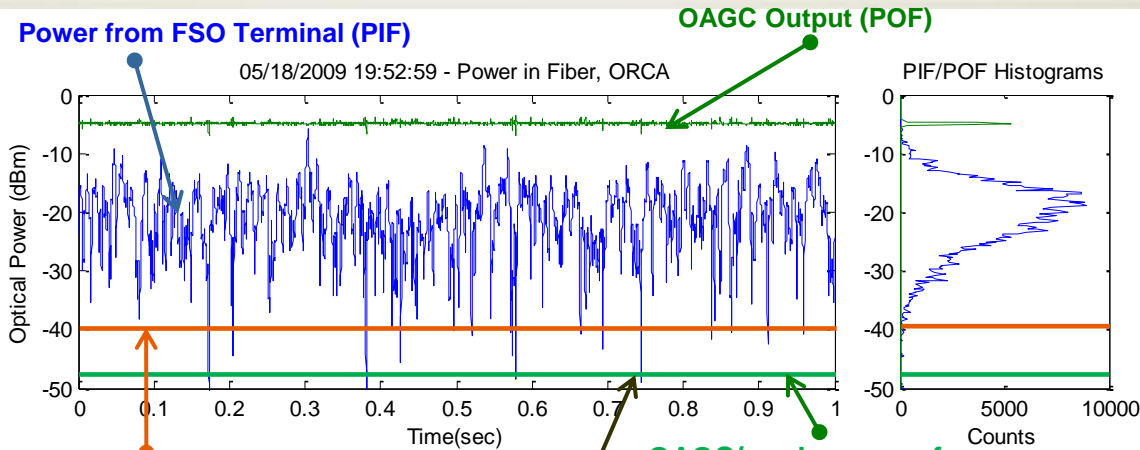
Airborne FSO Terminal



Ground FSO Terminal
(courtesy EAGLS program)

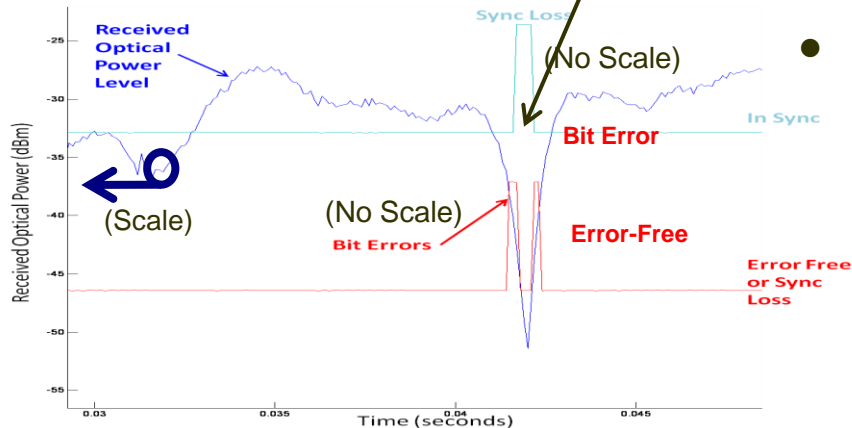
DARPA ORCA Program – NTTR Field Trial

DARPA ORCA program demonstrated the baseline FSO technologies used in FOENEX



OAGC/modem error free point for ORCA

OAGC/modem error free point for FOENEX.
7 dB improvement from ORCA



- 10 Gbps Ethernet signal
- 18 May 2009, 01:52 UTC,
 - Aircraft range = 183 km
 - Aircraft altitude = 25 kft MSL
- Field-measured OAGC response – OAGC output (POF) vs power from FSO terminal (PIF)
 - Uncorrectable atmospheric fading can lead to packet loss
 - Methods of mitigation:
 - Reduce link range – increases received power
 - Provide a method of retransmitting lost packets – One layer of the FOENEX approach

FOENEX Layered Approach to FSO Link Fade Mitigation

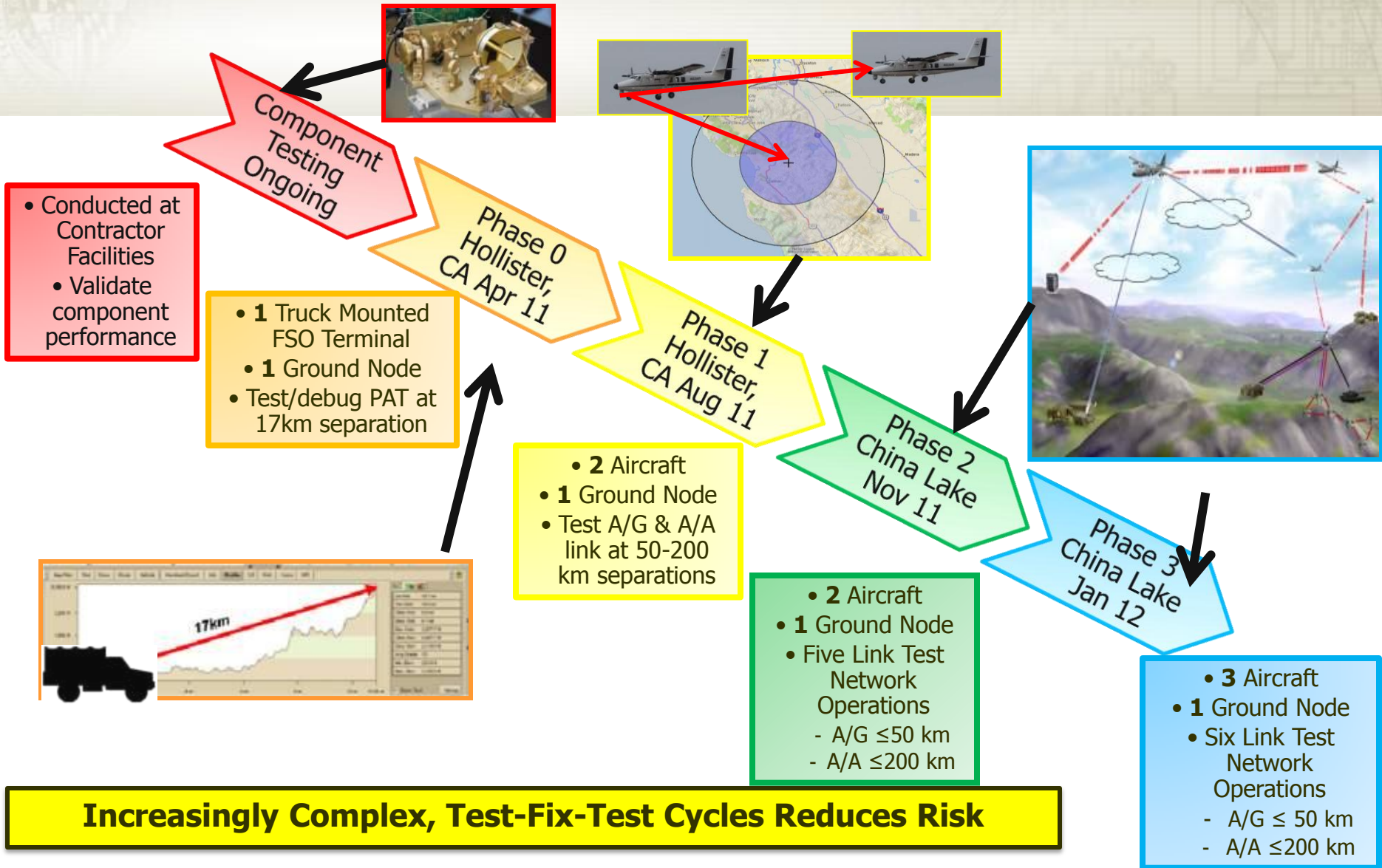
Physical layer methods

- Free space optical terminal
 - Field proven adaptive optics system reduces beam spread, increases collection efficiency
- Optical Automatic Gain Control system
 - Field proven system substantially reduces receive power variations. 60 dB dynamic range, < 1 ms response time
- Optical modem and FEC with near theoretical sensitivity

Network layer methods

- Packet retransmission systems (link or network)
 - Assures delivery of packets lost during deep fades.
- Deep queues at the nodes (link or network)
- Network re-routing or re-pointing (network only)
- Data replay (network only)

Multiple Test-Fix-Test Cycles



FOENEX Contractors, Agents, & Government Activities

Contractor/ Gov't Activity	Location	Role
Johns Hopkins APL	Laurel, MD	Prime Contractor : Systems Engineering/Integrator Lead
L3 Communications Systems West	Salt Lake City, UT	Hybrid Network Router and RF Link Development
AOptix Technologies, Inc.	Campbell, CA	Free Space Optical Terminal Development
Twin Otter International	Grand Junction, CO	Flight Test Aircraft Provider/Integrator
Systems Consultants	Fallon, NV	Flight Test Development /Execution
Naval Research Laboratory	Washington, D.C.	COTR / Technical Expertise/System Design