# ISS Fiber Optic Link Development Lessons Learned Journey

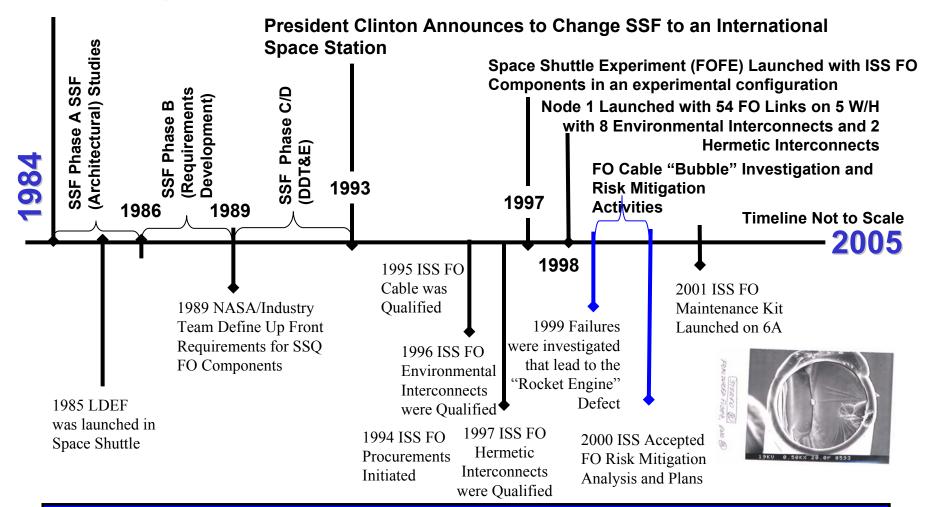


David Gill October 3, 2005 ISS Journey to Utilize Fiber Optic Technology



HB Avionics/Electrical Systems (AES)

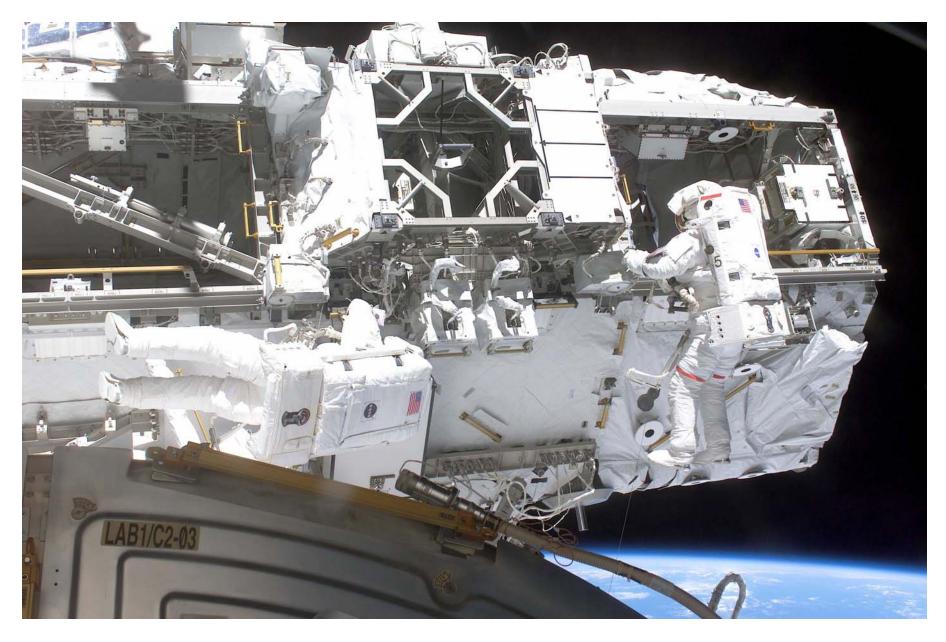
#### **President Regan Announces Permanent Manned Space Vision**



ISS was morphed from Space Station Freedom – Fiber Optics Technology was pushed into Vehicle Systems FO Components Embedded in ISS Systems ( BOEING

- Caution and Warning System
  - Internal Audio
- Payload Data System
  - Internal and External Ethernet
- Video System
  - Internal and External
- Used in All American ISS Elements except the Primary Power System Elements
- Used on ESA and NASDA Elements
- Russian Elements did not use FO

## FO Components Are Used on an S0 Element



### Fiber Optic Components / Qualified Performance



HB Avionics/Electrical Systems (AES)

SSQ Spec	SSQ P/N	SSQ Approved Supplier	Description	Thermal / Environment	Mechanical Environment	Optical Perf. Req's
21635	NZGC	Amphenol	Circular Connectors	• <u>Thermal Shock</u> 25 cycles -100°C to +150°C	Durability 500 mate cycles NATC 1000 mate cycles NZGL	Ambient Loss Substitution Loss <
21636	NRP	ITT Cannon	Rack and Panel Connectors	• <u>Thermal Life</u> <b>21635:</b> -115°C & 150°C for	<u>Maintenance Aging</u> 10 insert- removal cycles	0.4 dB change Induced Loss < 0.3 dB
21637	NU	G&H Technologies	Umbilical Connectors	500 hours <b>21636:</b> 150°C for 500 hrs <b>21637:</b> -115°C & 150°C for 250 hours • <u>Differential Temp</u> Δ150°C Low end -66°C max.	Salt Spray           21635 & 21637:           5% for 96 hrs           21636:           5% for 48 hrs           21637:           Random Vibration           21635 &           3.5 min/axis, 1.0           G <sup>2</sup> Hz.           21636:           3 min./axis, 43.7 G           RMS           21637:           7 min/axis, 1.0G <sup>2</sup> Hz	End of Life Loss Average = 0.85 dB Std. Dev. = 0.28

SSQ's Specifications were developed to define the requirements Common Components for ISS.

Fiber Optic W/H Component / Qualified Performance BOEING

SSQ Spec	SSQ P/N	SSQ Approved Supplier	Description	Thermal / Environment	Mechanical Environment	Optical Perf. Req's
21635	NZGC	Amphenol	Circular Connectors	• <u>Humidity</u> <b>21635:</b> 240 Hours at 95%	<u>Mechanical Shock</u> 21635 & 21637: 3 per axis, 75G, 11	
21636	NRP	ITT Cannon	Rack and Panel Connectors	<b>21636:</b> 10 cy of 16 hours, 1 cy. = 40°C @ 94% RH and 40°C @	millisecond <b>21636:</b> 3 axis, 30G, 11 millisecond	
21637	NU	G&H Technologies	Umbilical Connectors	<ul> <li>85% RH</li> <li>21637:</li> <li>N/A for Fiber Optics</li> <li>Storage</li> <li>21635:</li> <li>-100°C to +120°C at 10<sup>-5</sup> torr</li> <li>21636 &amp; 21637</li> <li>-115°C to 150°C</li> </ul>	Mating Forces (max)           21635:           Shell<25, < 25 lbs.;	

Fiber Optic W/H Component / Qualified Performance

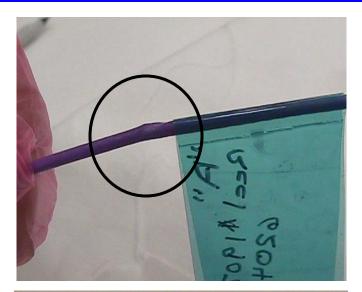
SSQ Spec	SSQ P/N	SSQ Approved Supplier	Description	Thermal / Environment	Mechanical Environment	Optical Perf. Req's
21654	NFOC	Brand Rex		• Fungus – none • Odor < 2.5 rating • Toxicity NHB 8060.1 • Vacuum Stability <1% mass loss, $1X10^{-6}$ torr @ $125^{\circ}C$ • Survival Life -135^{\circ}C & +157^{\circ}C @ $1X10^{-6}$ torr • Flammability $30\% O_2 70\% N_2 @ 10$ PSI, self-extinguishing • Thermal Shock 25 cycles,-100°C to $150^{\circ}C$ per MIL-STD 202 Method 107 • Radiation Resistance 118 Krads @ 0.1 Rad/sec	<ul> <li>Stippability – <ul> <li>Jacket by hand</li> <li>Fiber coating &gt; <ul> <li>2.5 KG</li> </ul> </li> <li>Cyclic Flexing 2000 cy</li> <li>Crush 22.6 KG for 60 sec.</li> <li>Cable Bend 1.25"R</li> <li>Cable Weight 9KG/Km</li> <li>Jacket Shrinkage 0.4%</li> </ul></li></ul>	Induced Loss < 0.3 dB Substitution Loss < 0.3 dB End of Life 6 dB/Km

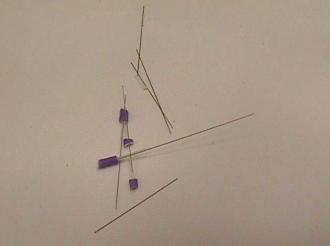
## **ISS Fiber Optic Cable Lessons Learned**

HB Avionics/Electrical Systems (AES)

- Design Requirements
  - Fiber Glass Selection
    - Multimode
    - Radiation Hardened
    - Carbon Coated
    - Polyimide Coating
  - Jacket Design and Construction
    - Semi-loose Tube Construction
    - Strength Member
    - Jacket
- Acceptance Requirements
  - Dimensional Controls on Fiber/Coatings
  - Zero Defects on Coatings
  - Cable Visual Inspection
  - Optical Loss Testing
  - Packaging
- Qualification Requirements
  - Quantity of cable tested
  - Quality of the testing
- Supplier Management

## SSQ 21654 FO Cable was Qualified Twice







Example of a Non-conformance Closure Post "Bubble" Alert

HB Avionics/Electrical Systems (AES)

•										
•	DISCREPANCY 05									
•	********** ENTER DEFECT DESCRIPTION BELOW: ************************************									
٠	14 REELS OF FIBER OPTIC CABLE WAS TESTED PER									
	PROCEDURE									
٠	1T80265 "C" WITH THE FOLLOWING RESULTS:									
٠	REEL #	GOOI	D PCS.	FT. DE	FECT PCS.	FT				
•	190764	4	135.44	3	3					
•			182.76	6	7					
٠	100501	0	0	SCRAP R	EEL TOTAL =	: 175.32				
•	100472	11	349.12	12	17.5					
٠	190837	5	442	4	4					
٠	190757	0	0	SCRAP R	EEL TOTAL =	: 320.56				
٠	100454	20	532.3	25	39.3					
٠	190759	0	0	SCRAP R	EEL TOTAL =	: 518.88				
•	190747	8	778.44	7	7					
•	190751	38	1257.44	47	68.5					
•	190859	2	208.60	1	1					
٠	190749	0	0	SCRAP R	EEL TOTAL =	1198.96				
•	• NOTE: TWO REELS # 190835 (308.52 FT) & # 190752 (863.32 FT) HAVE									
•	ZERO DEFECTS AND ARE COMPLETE AND ACCEPTABLE									
•										

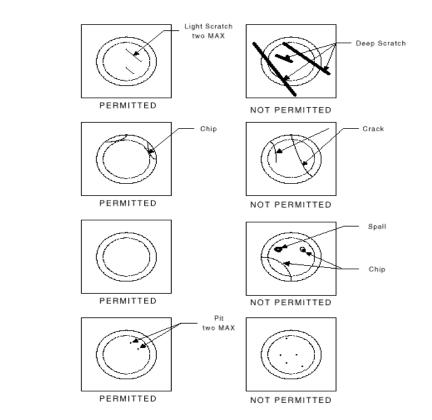
• E.M. THOMSON A033310 A3-436 26NOV01

**ISS Fiber Optic Interconnects Lessons Learned** 



HB Avionics/Electrical Systems (AES)

- Environmental Sealed Connector Design Requirements
  - Termini Materials
  - Tolerance Stacks different than Traditional Environmental Connectors with copper
  - Termini
    - Terminations
      - Cure Materials
      - Cure Profiles
      - Concave vs. PC Polish
      - Full fill vs end fill
      - Inspection and Verification
    - Insertion and Removal
    - Optical Testing
  - Number of Insert Configurations
  - Mating Forces and Torques
  - Backshells
  - Mixed Media Types
- Acceptance Requirements
  - Visual Inspections
  - Optical Loss Test
- Qualification Requirements
  - Quantity of configurations tested
  - Quality of the testing
- Supplier Management



# SSQ 21635, 21636 and 21637 Connectors included FO Capabilities

#### FO Termini and NZGL Environmental Connector Inserts





ISS Fiber Optic Interconnects Lessons Learned

- Hermetic Sealed Connector Design Requirements
  - Several Insert/Shell Size Configurations
  - Dimensions of small parts
  - Termini Materials and Seals & Processes
  - Full Fill vs End Fill
  - Inspection and Verification
  - Production Rework of Termini
- Acceptance Requirements
  - Verification of Polish Quality
  - Verification by Test
- Qualification Requirements
  - Quantity of configurations tested
  - Quality of the testing
- Supplier Management

## Only SSQ 21635 included Capabilities with Hermetic Sealed FO Termini

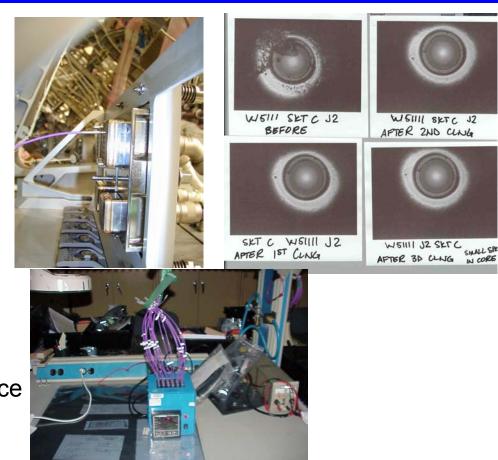




ISS Fiber Optic Wire Harness Assembly and Integration Lessons Learne more ING

HB Avionics/Electrical Systems (AES)

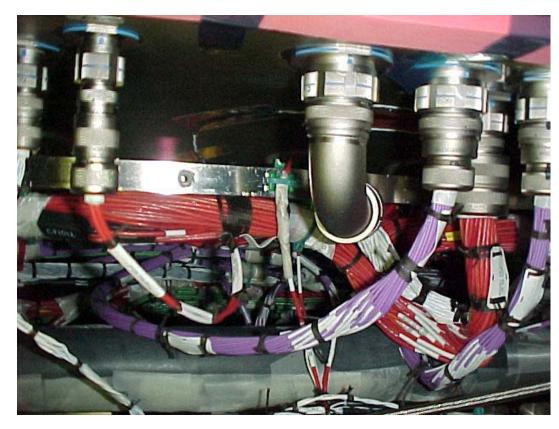
- Design Requirements
  - Bend Radii
  - Clamping
- Acceptance Requirements
  - Visuals
  - Testing
    - Post Installation
    - Functional Performance
       in System



## Fiber Optics Were Embedded throughout ISS Elements

## FO W/H Installed in US Lab









## **ISS Fiber Maintenance Kits**



- All Fiber Maintenance Equipment is planned to be flown in 5 different kits/assemblies:
  - Optical Time Domain Reflectometer (OTDR) 1F92564-1
  - Reel Test Softpack Assembly 1F92761-1
    - Softpacks
    - FO Test Adapter Assembly (Patch Panel)
    - OTDR to Test Adapter Assembly patch cable
    - OTDR Power Cable (to 28VDC source)
    - Visual Fault Finder (low power HeNe laser)
    - ST/SSQ Cleaning Kits
  - Link Segment Softpack Assembly 1F92703-1
    - Softpacks
    - Fiber Replacement Links (quantity 36 links in 12 configurations)
    - Backshell Removal Tool
    - Backshell Plyers
    - Fiber Terminis Inseration/Extraction Tools (10)
    - Tie Wraps (100)
  - Test Adapter Softpack Assemblies 1F92676-X:
    - Softpack Assemblies (quantity 8) –1, -501, -503, -505, -507, -509, -511, -513
    - Test adapters (quantity 15) grouped at next assembly (softpack) in logical groups
  - EVA PDGF Contingency Wire Harness Assembly 1F92665-1

FO Tool Kit Development – Primary Fault Isolation Tools





Optical Time Domain Reflectometer (OTDR)

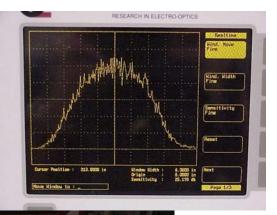




OTDR/Reel Patch Cable (QTY 3)

Reel Assembly acts as breakout box with 37 termini test capability

OTDR Signature of an SSQ Mate I/F





Flight Test Adapters (15 different in 8 differentSoftpack Assemblies))



Visual Fault Finder (VFF)

FO Tool Kit Development – Primary Contingency Tools

HB Avionics/Electrical Systems (AES)



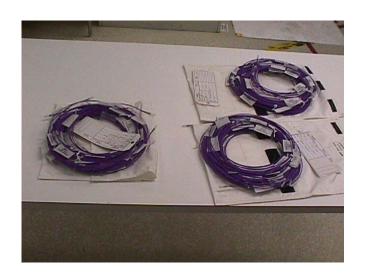


Backshell Holding Tool 2

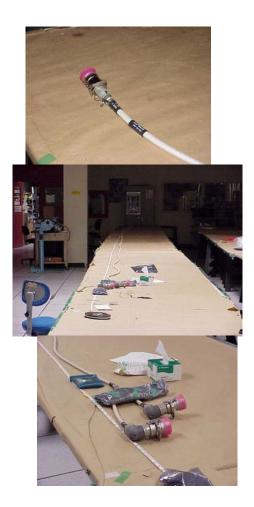


Backshell Holding Tool 1





Terminated Flight Links (QTY 36 in 12 Configurations stored In four diffent low level softpacks)



Multi-purpose EVA PDGF Contingency Cable

Insertion/Extraction Tools (QTY 10)

## FO Tool Kit Development



- 4/00 ATP for OTDR Development
- 5/00 OTDR Requirements Developed
- 7/00 ATP for FO Tool Kit Development
- 9/00 FO Tool Kit Requirements Developed
- 11/00 OTDR & FO Tool Kit Prototypes Completed
- 11/00 OTDR Outgas
- 10/00 OTDR Radiation Testing
- 12/00 FO Tool Kit Prototype Testing Initiated
- 12/00 PDGF Crew Walkdown with installation scenarios
- 12/00 OTDR Burn-in Testing
- 01-01 OTDR Vibration Testing
- 01/01 OTDR Thermal Cycling Testing
- 12/00 3/01 FO Cable Functional ATPs
- 3/01 Electrical Cable (28VDC) Functional ATP
- 1-3/01 Other COTS tools and miscellaneous Outgassed
- 3/16/01 Kit Sharp Edge Inspection
- 3/16/01 Kit Connector Fit Checks (IVA OTDR, Patch Cables, Reel, and all test adapters
- 3/20/01 Crew Walkdown and Bench Review
- 3/23/01 Stowage in MPLM Racks
- 3/26/01 Equipment Stowed in MPLM
- 3/26/01 Development Equipment used in Flight-like System Level Testing (still ongoing as of 6/9/01)
- 4/19/01 6A Launch
- 6/12/01 Operations Training Session
  - FO Tool Kit Deorbited
  - FO Tool Kit Placed in KSC Stores



FO Tool Kit Prototype Test Set



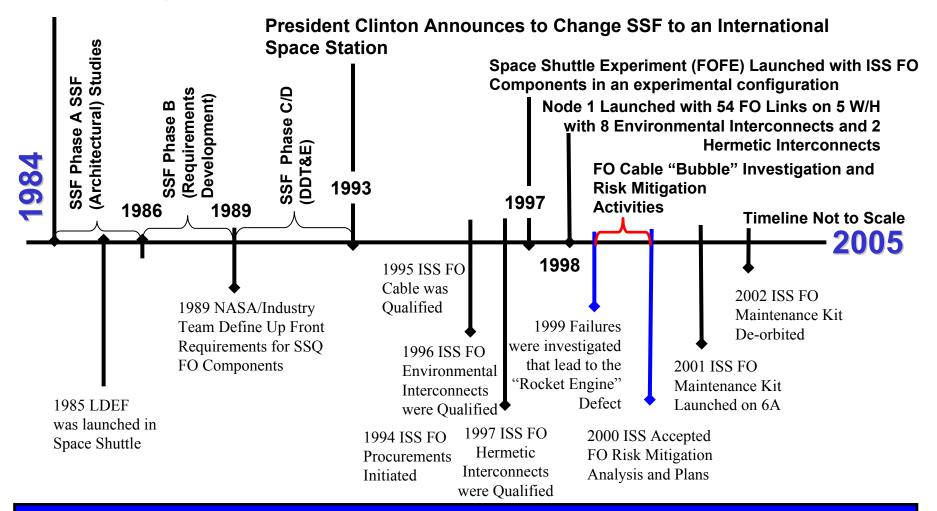
Crew Bench Review 3/20/01

ISS Journey to Utilize Fiber Optic Technology



HB Avionics/Electrical Systems (AES)

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As of September 2005, ISS has experienced 100% Success of Fiber Optic Components and there are well over a thousand links on orbit in operation