Low Boom Flight Demonstrator Project

Operational Challenges Associated with X-59 and F-15 Chase Aircraft Life Support System (LSS) Design

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SAFE Symposium October 14-16, 2019

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Unlimited Distribution

SAFE Symposium, Oct 14-16, 2019

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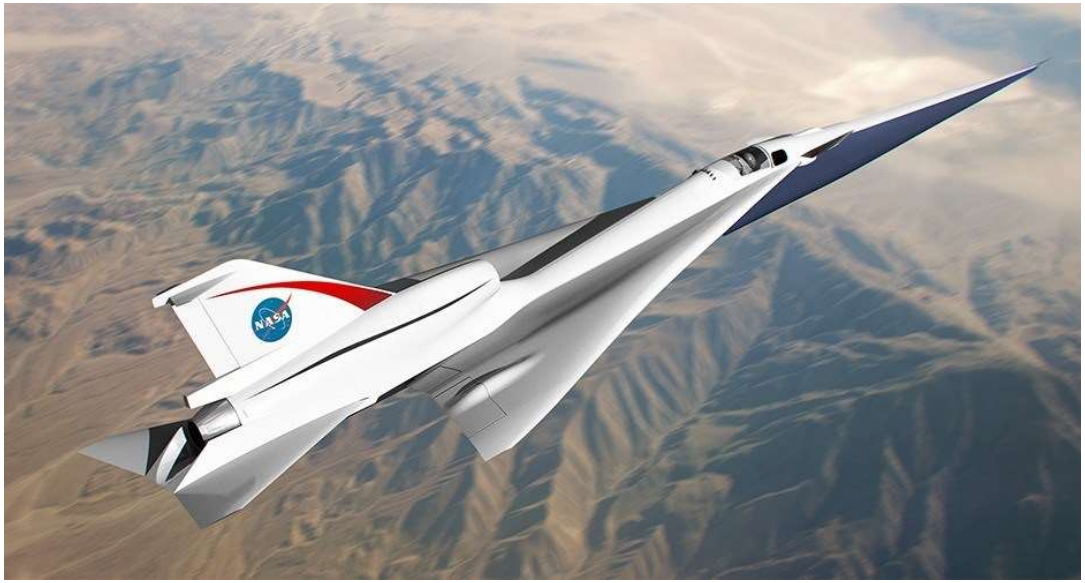
- Questions



Goals of Brief

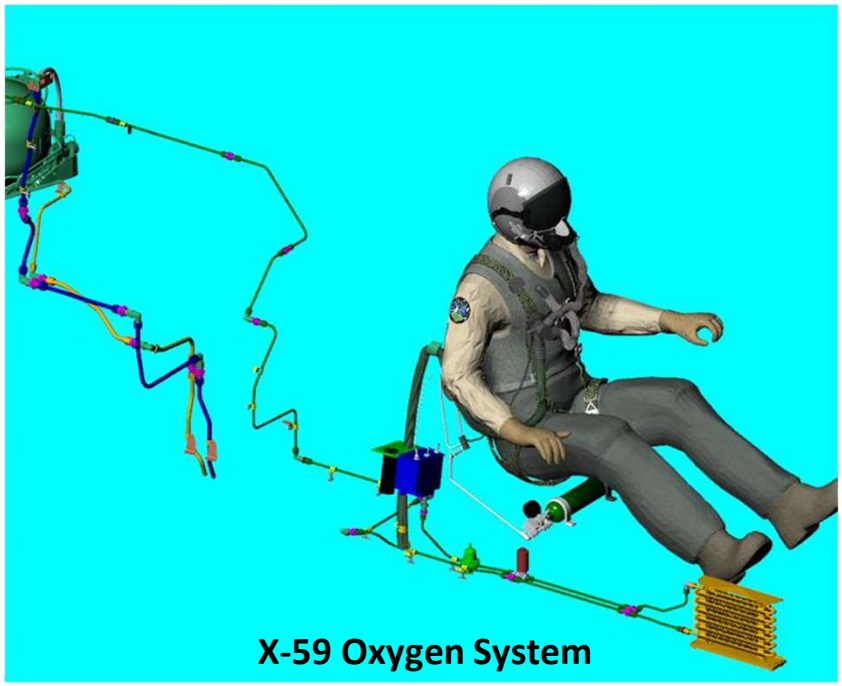
- Review LBFD program
  - X-59 and F-15 chase aircraft
- Help understand how X-59 program goals affected design
- Describe several X-59 and F-15 chase aircraft design decisions
  - Very specific examples, with relevance to other designs
  - Consider Challenges, Tradeoffs and Design Solutions
  - Focus on Life Support System (LSS)
  - Maintenance Perspective

X-59 Project/Mission Background

- **Project Overview:**
  - Design and build a piloted, large-scale supersonic X-plane with technology that reduces the loudness of a sonic boom to that of a gentle thump
  - Fly the X-plane over select U.S. communities to gather data on human responses to the low-boom flights and deliver that data set to U.S. and international regulators.
- **X-59 (and chase!) Aircraft Design Limits**
  - 60,000 ft
  - 450 KEAS / 1.7 Mach
- **Typical Mission Flight Profile**
  - Two runs at Mach 1.4
  - 20 minutes at 50K-55K ft
  - Standard 5 psi differential cabin pressure schedule
- **Routine Operations (X-59 plus F-15 chase)**
  - Up to 3 flights per day
  - 100% oxygen to pilot during all ops
  - 30 minute pre-breathe (to reduce DCS risk)
- **Immediate Descent if:**
  - Cabin depressurization
  - Oxygen System Malfunction

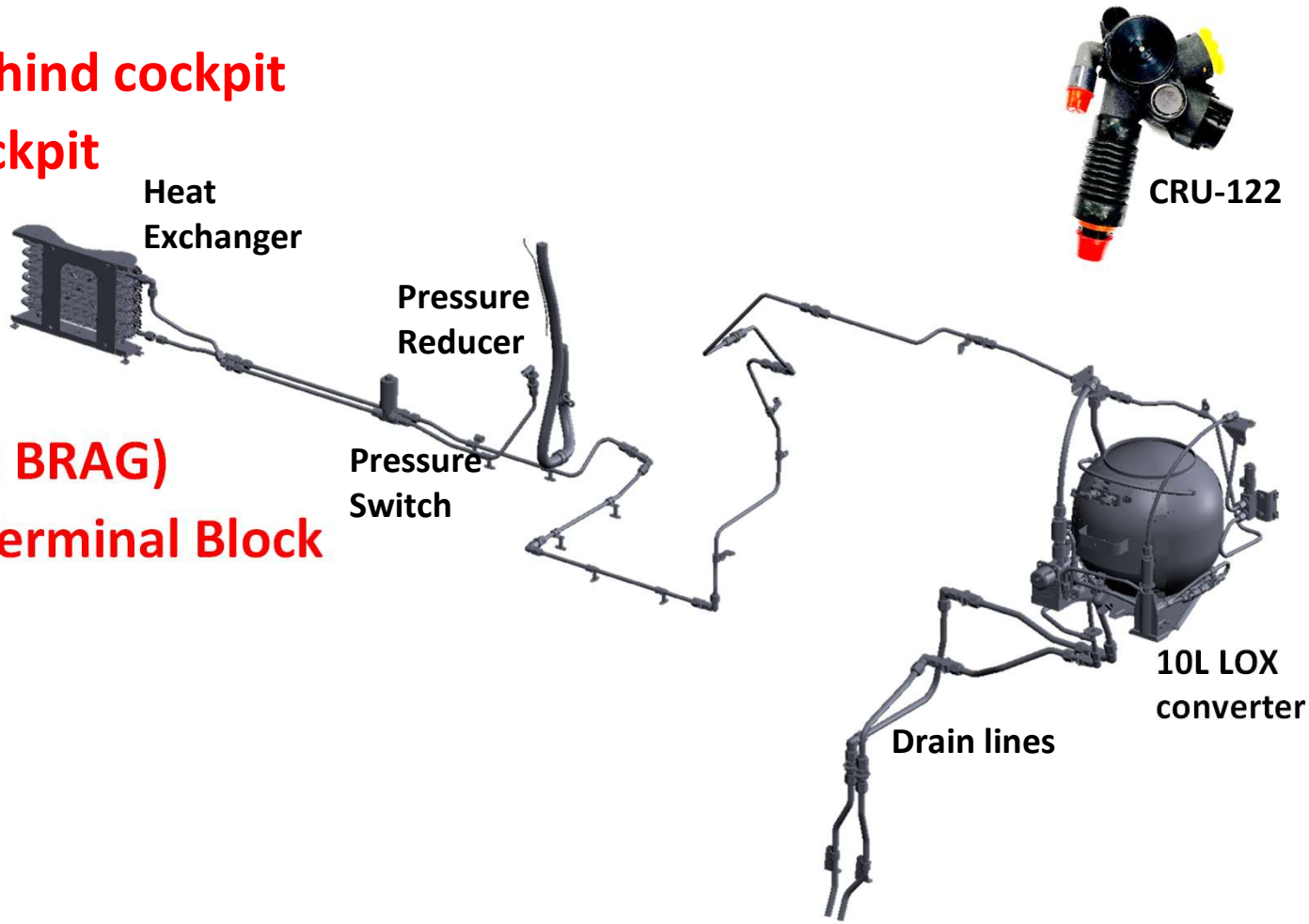
Summary of LBFD Program Aircraft LSS Oxygen Systems

- **Next four pages show the four systems discussed in this brief**
  - **X-59 Primary Oxygen System**
    - **LOX-based**
    - **No OBOGS**
  - **X-59 Emergency Oxygen System (EOS)**
    - **50 cu in compressed oxygen gas**
  - **F-15 Primary Oxygen System**
    - **LOX-based**
    - **No OBOGS**
  - **F-15 Emergency Oxygen System (EOS)**
    - **50 cu in compressed oxygen gas**



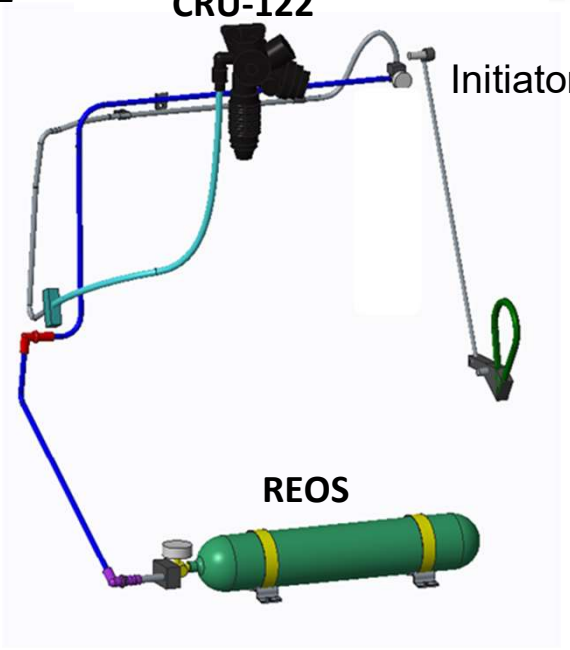
X-59 Primary Oxygen System

- 10L LOX converter behind cockpit
- Heat Exchanger in cockpit
- Pressure reducer
- Pressure switch
- LOX qty indicator
- PMBR (similar to F-22 BRAG)
- CRU-122 Integrated Terminal Block
- MBU-20P mask



X-59 Emergency Oxygen System

- **50 cubic inch bottle and regulator head (F16 - REOS)**
  - Beneath SSK
  - Pressure gage
- **T-38 shear pin initiator in seat back**
  - Removed pressure reducer from head
  - Wire pull actuation
  - pressure gage
- **CRU-122 Integrated Terminal Block**
- **MBU-20P mask**



F-15 Primary Oxygen System Modifications

Current System

- 10 Liter Lox Bottle
- CRU-93 Panel Mounted Regulator
- CRU-60P Integrated Terminal Block

CRU-60P

CRU-93

Lox Bottle

System Modified for X-59 Program

- 10 Liter Lox Bottle
- PMBR Panel-Mounted Regulator
- CRU-122 Integrated Terminal Block
- Pressure Reducer

Pressure Reducer

CRU-122

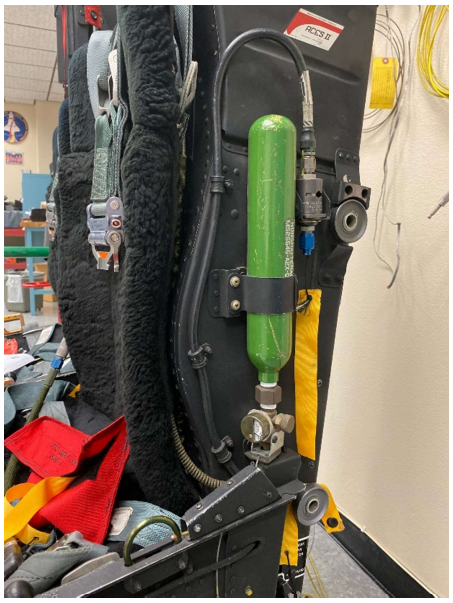
PMBR

F-15 Emergency Oxygen System Modifications

Current System

- 22 cubic inch bottle, xxx regulator head
- CRU-60P Integrated Terminal Block

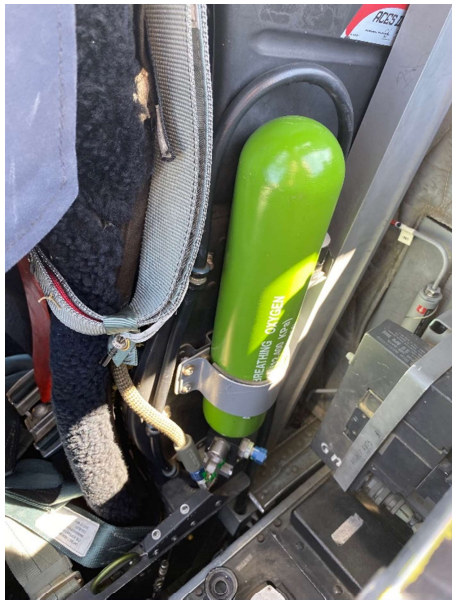
CRU-60P



System Modified for X-59 Program

- 50 cubic inch bottle and regulator head (F16 - REOS)
- CRU-122 Integrated Terminal Block

CRU-122

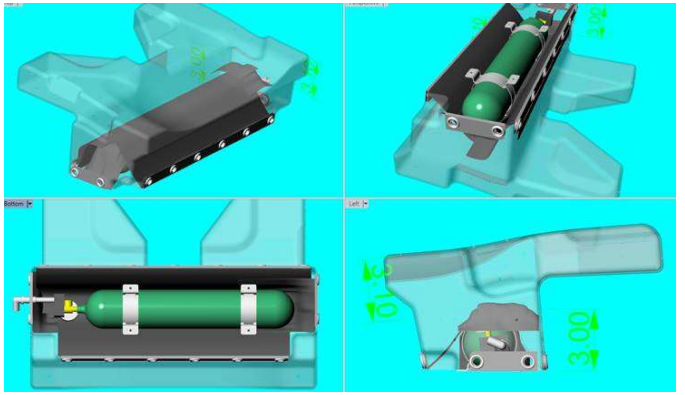


Summary of LBFD LSS Oxygen System Operational Challenges

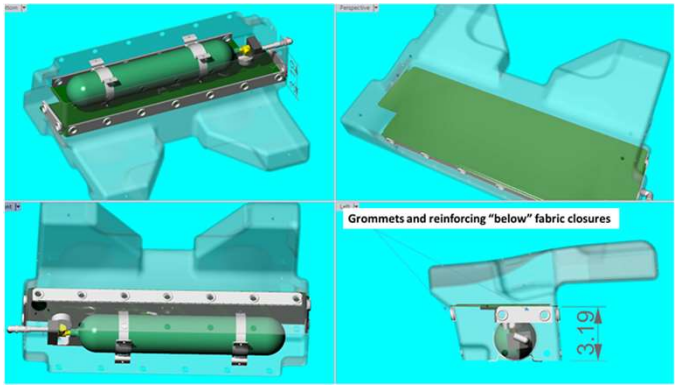
- **Next pages outline several LSS challenges from maintenance standpoint**
  - **X-59**
    1. X-59 EOS tank fit within SSK
    2. LOX converter fit and maintenance
    3. EOS LOX Qty daily checks
  - **F-15**
    1. Installing Panel Mounted Breathing Regulator (PMBR)
  - **Both**
    1. Incorporating a New Demand Regulation Head to EOS Oxygen Supply
    2. Reducing pressure to PMBR

X-59 LSS Operational Challenge #1: EOS oxygen tank fit within SSK

- **Goals:**
  - Ensure X-59 can carry sufficient emergency O_2
- **Challenges:**
  - 50 in^3 O_2 volume required
    - Provide >25 lpm for ejection and fly down from 60K ft
  - T-38 seat back insufficient to fit flight rated hardware
  - Need to use space beneath seat for oxygen
  - Infringes on SSK contents, esp life raft
- **Resolution:**
  - Redo SSK to accommodate oxygen bottle
  - Employ space saving life raft and fewer rations



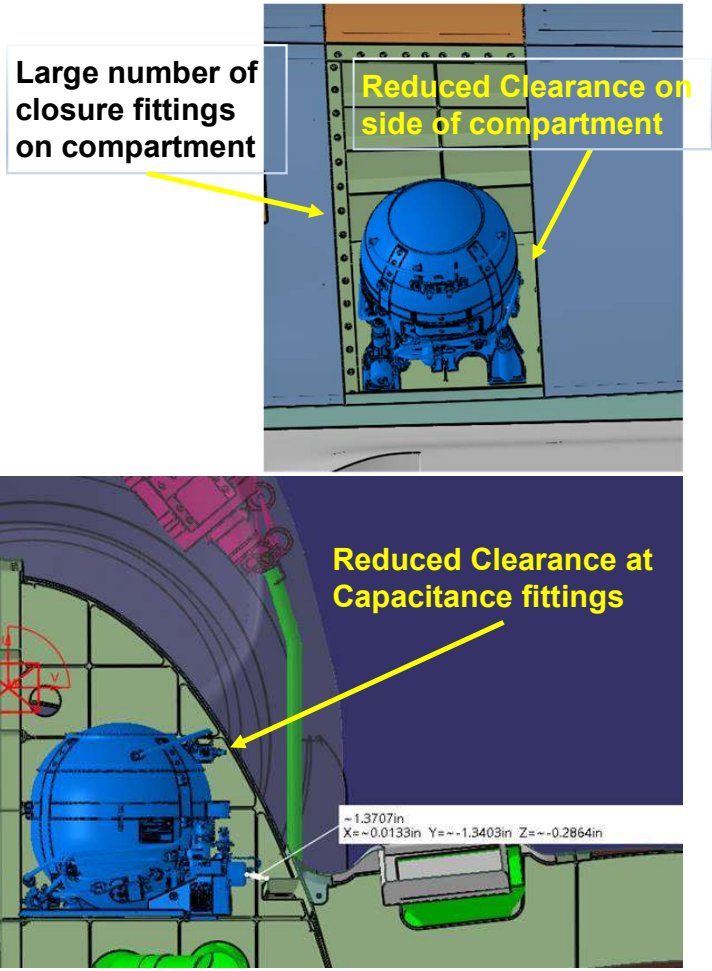
Initial SSK/EOS cylinder fit: CAD model



Final SSK/EOS cylinder fit: CAD model

X-59 LSS Operational Challenge #2: LOX Converter Fit and Maintenance

- **Goals:**
  - Ensure LOX converter can support mission parameters
- **Challenges:**
  - Timely oxygen servicing: (turnaround times)
    - AFRC procedures: no oxygen filling on acft – converter removal
    - Many fittings to secure oxygen compartment cover
    - Small mounting space: possible obstructions on sides and front
- **Resolution:**
  - Adopt elbow capacitance fittings
  - LL: Work with LM team to ensure adequate clearance



LOX converter/compartment fit: CAD model

X-59 LSS Operational Challenge #3: EOS Oxygen Quantity Daily Checks

- **Goals:**
  - Ensure EOS parameters (leaks, pressure, etc…) can be checked easily
- **Challenges:**
  - Oxygen cylinder beneath seat precludes easy optical access
  - Existing gages have coarse resolution
  - Prefer NOT to remove SSK to simply view cylinder pressure (CAD?)
  - Need to check pressure in tubing also at initiation head
- **Resolution:**
  - Finer resolution gage installed at initiator valve – easier to see through pilot seat back
  - Small inspection port added to port side of seat frame and SSK
  - Allows crew chief to inspect pressure with mirror

CAD model of inspection port and view

F-15 LSS Operational Challenge #1: Installing Panel Mounted Breathing Regulator (PMBR)

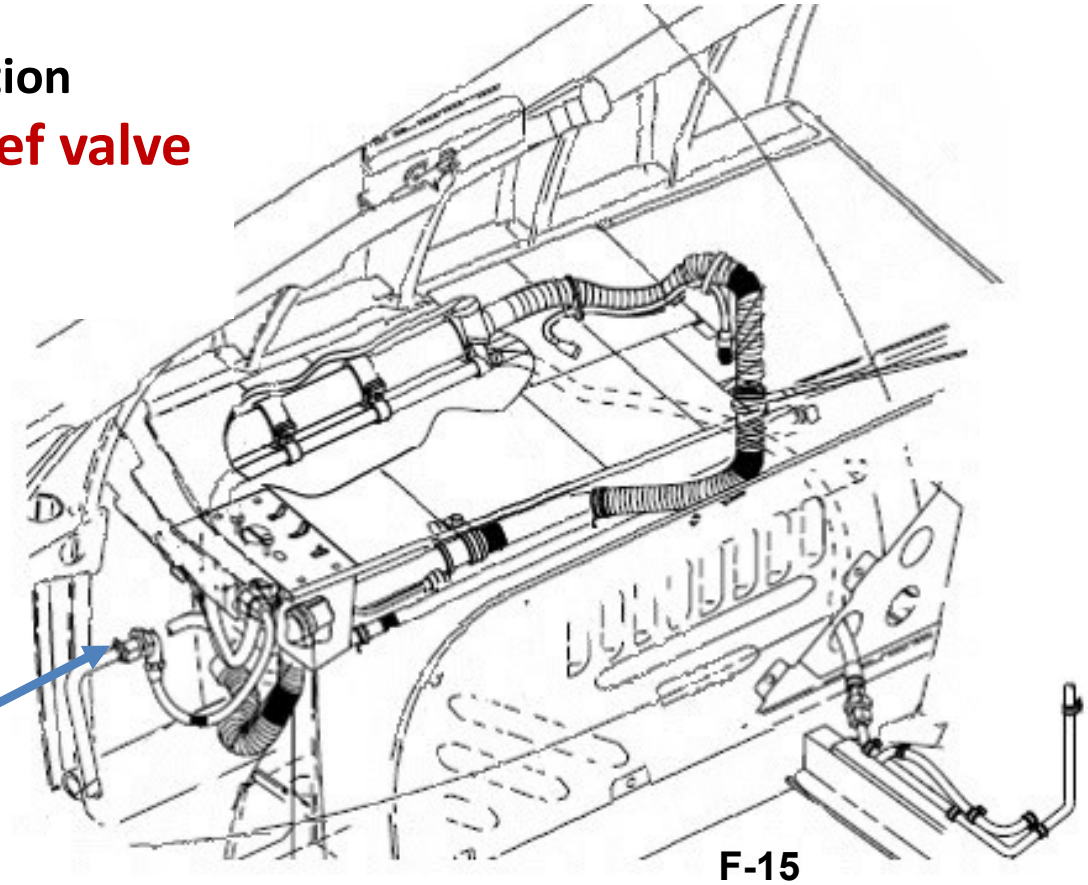
- **Goals:**
  - **Have a regulator capable of going to 60000 ft altitude**
  - **Use currently flight approved equipment**
- **Challenges:**
  - **Current F-15 regulator CRU-93 ceiling: 50000 ft altitude**
    - **Flight ceiling 60000 ft**
  - **BRAG Valve exclusively F-22 acft**
  - **BRAG requires ECS air for G-control (**Following slide**)**
    - **Currently other side (left) of acft**
    - **Currently ECS inlet pressure is too high for PMBR**
- **Resolution:**
  - **Boeing, Honeywell agreed to sell NASA BRAG-like valve**
    - **Removing switches not required with LOX and renaming regulator**
      - **Panel Mounted Breathing Regulator (PMBR)**

"Combat Edge" Oxygen Regulator CRU-93

BRAG Panel Mounted Regulator

F-15 LSS Operational Challenge #1: Installing PMBR (Cont.)

- **Use current oxygen lines in acft**
  - Easy to return to original configuration
- **Install pressure regulator and relief valve**
  - F-15 LOX supplies 80-120 psig
  - PMBR requires 20-75 psig



F-15

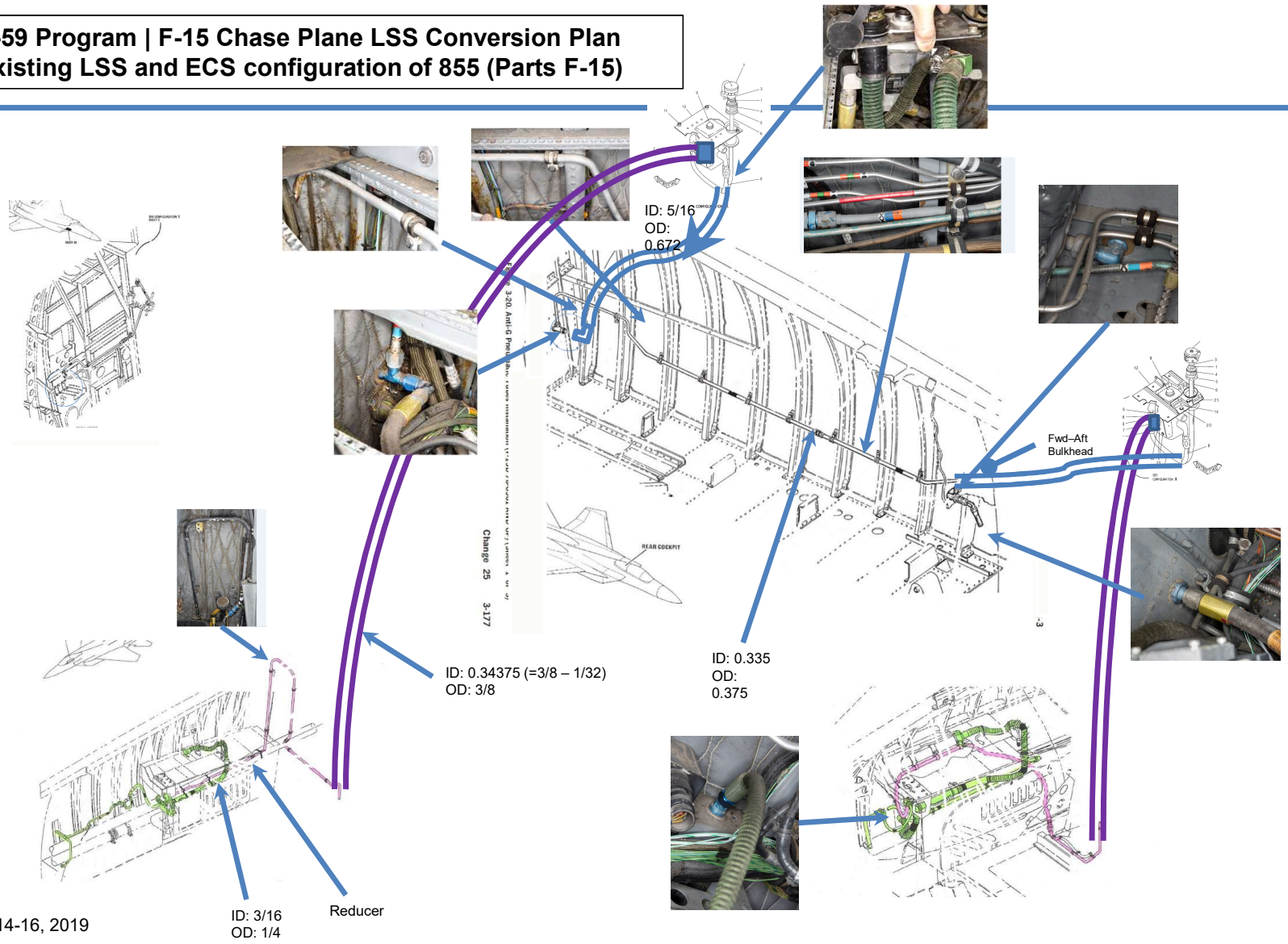
- Supply line from LOX bottle (post heat exchanger)
- Pressure regulator and a 75 psig relief valve

F-15 LSS Operational Challenge #1: Installing PMBR: ECS Air to PMBR (cont)

- **Goals:**
  - **Supply ECS air from left hand side of the F-15 to the right to connect to the PMBR**
  - **Possibly use current ECS air line from Anti-G valve to CRU-93/8 to supply pressure to right hand side of acft (**Following slide**)**
- **Challenges:**
  - **Possible supply pressure from ECS is too high for PMBR (30 +/- 3 PSI)**
    - **Acquiring flight certified ECS regulator**
  - **Acquiring Anti-G supply pressure and line pressure ratings from SPO**
- **Resolution:**
  - **Route new lines to right hand side of acft**
  - **Run tests to determine supply pressure, to decide if regulator is required**
    - **Work with companies to acquire regulator**

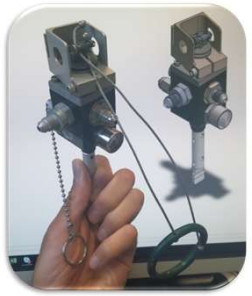
F-15 Anti-G Valve

X-59 Program | F-15 Chase Plane LSS Conversion Plan
Existing LSS and ECS configuration of 855 (Parts F-15)

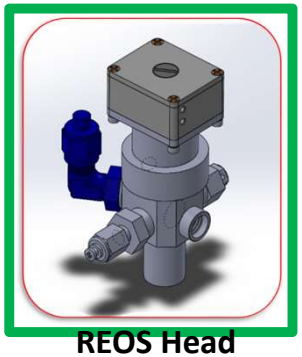


F-15 and X-59 LSS Operational Challenge #1: Incorporating a New Demand Regulation Head to EOS Oxygen Supply

- **Goals:**
  - Desire F-15 chase aircraft EOS supply compatibility w/CRU-122
  - Desire commonality with X-59 EOS
- **Challenges:**
  - Legacy NASA F-15 EOS regulator heads are currently being evaluated for rebuild and compatibility check (CRU-122)
  - REOS heads are newer, CRU-122 compatible, more pressure protection
  - Periodic maintenance requirements for REOS heads
    - Require removal from acft every 180 days for inspections
    - Possible adverse impact on post-flight turnaround
    - May require larger lot size to ensure availability of flight-ready units
- **Resolution:**
  - Backup plan to use unsupported NASA F-15 heads (program risk vs in hand)
  - Choose REOS regulator units for BOTH X-59 and F-15 (commonality)
  - REOS units tested at KBR worked well for all conditions
  - Purchase sufficient REOS units to have ready spares at all times



Legacy NASA F-15 Head



REOS Head

REOS Head Being Tested at KBR

F-15 and X-59 LSS Operational Challenge #2: Reducing Pressure to PMBR

- **Goals:**
  - Ensure PMBR has proper input pressures
- **Challenges:**
  - LOX converter outputs 70-110 psi during routine ops
  - PMBR requires 40-70 psi for optimal performance
  - Pressure reducer required to optimize input pressure
  - Flight qualified pressure reducer minimize dev costs!
- **Resolution:**
  - Adopt flight-qualified pressure reducer (mfr recc)
  - Test reducer at KBR to ensure adequate performance
  - Test reducer on F-15 prior to X-59 flights

Status/Future Plans

- **Development and Integration Test Schedule:**
  - **Benchtop tests:** present
  - **KBR Final Testing:** Tentatively February 2020
  - **Install and test system in F-15:** early 2021
    - F-15s currently going though heavy mod to prepare for chase activities
  - **Install system in X-59:** Early 2021
  - **X-59 First flight:** Summer 2021

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Questions

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