

# Adaptation of LSP Capability for Use on F-22 Raptor Primary Structure at an Aircraft Modification Depot

2<sup>nd</sup> International Conference on Laser Peening  
April, 2010



LSP Conference Presentation April 2010  
David Jensen, F-22 Air Vehicle Technology  
206-544-2872

# Adaptation of LSP Capability for Use on F-22 Raptor Primary Structure at an Aircraft Modification Depot

F-22 Mobile LSP Maturation



## Agenda

Purpose: Provide an overview of the requirement, challenges, and implementation of LSP on the F-22

- F-22 Raptor Structural Retrofit Requirement
- Glass Bead Peen Application (SRP1)
- LSP Attributes and Challenges
- LSP Maturation Program (LSPM)
- Implementation at Depot (SRP2)
- Summary of Lessons Learned

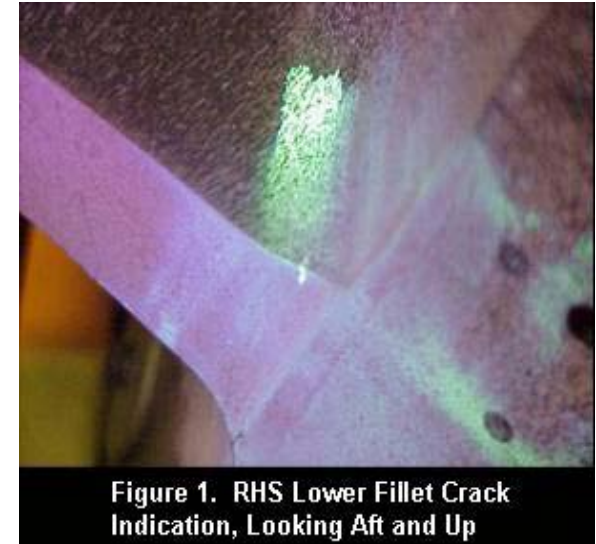
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# F-22 Raptor Structural Retrofit

F-22 Mobile LSP Maturation

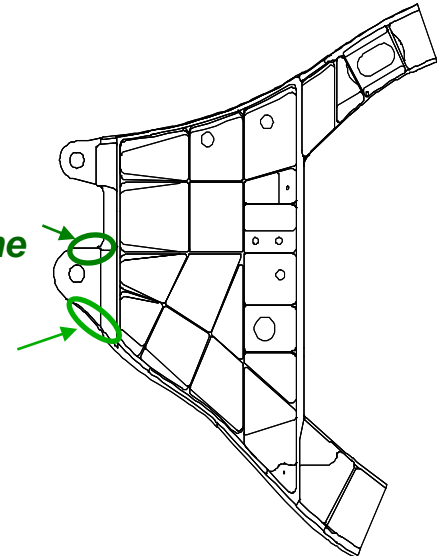


- **Reduced Risk of Fatigue Cracking at Lugs Desired**
  - Design adjustment applied to majority of fleet
  - Early aircraft were slated for life extension retrofit
- **Glass Bead Peening (GBP) implemented “at risk”**
  - Coupon test data suggested risk was low
  - Imparts beneficial surface compressive layer
  - Some booms GBP’d during production (at MIC)
  - Earliest aircraft received GBP during first retrofit program - SRP1
- **Peening benefit test program initiated (DO-30)**
  - Includes both lug elements and test frames
  - GBP for both fleet cases above
  - Laser Shock Peen (LSP) over GBP
  - Sets fleet maintenance requirements
- **GBP retrofit, test program, and production were all executed in parallel**



Peen upper  
radius of frame  
2 lower lug

Peen lower  
radius of all  
lower lugs

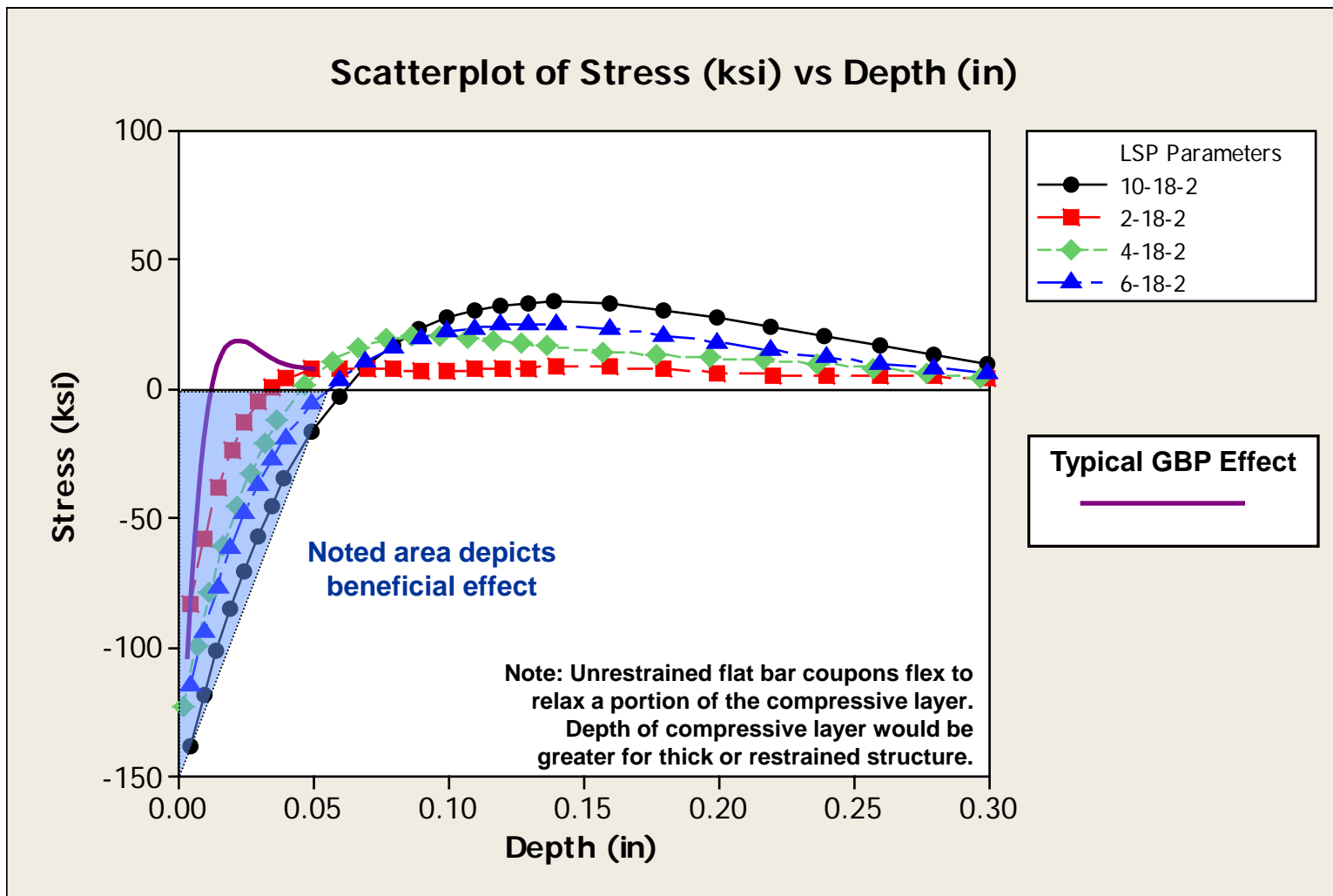


# F-22 Raptor Structural Retrofit

F-22 Mobile LSP Maturation



## LSP Surface Compressive Effect EMD "Flat Bar" Data



# F-22 Raptor Structural Retrofit

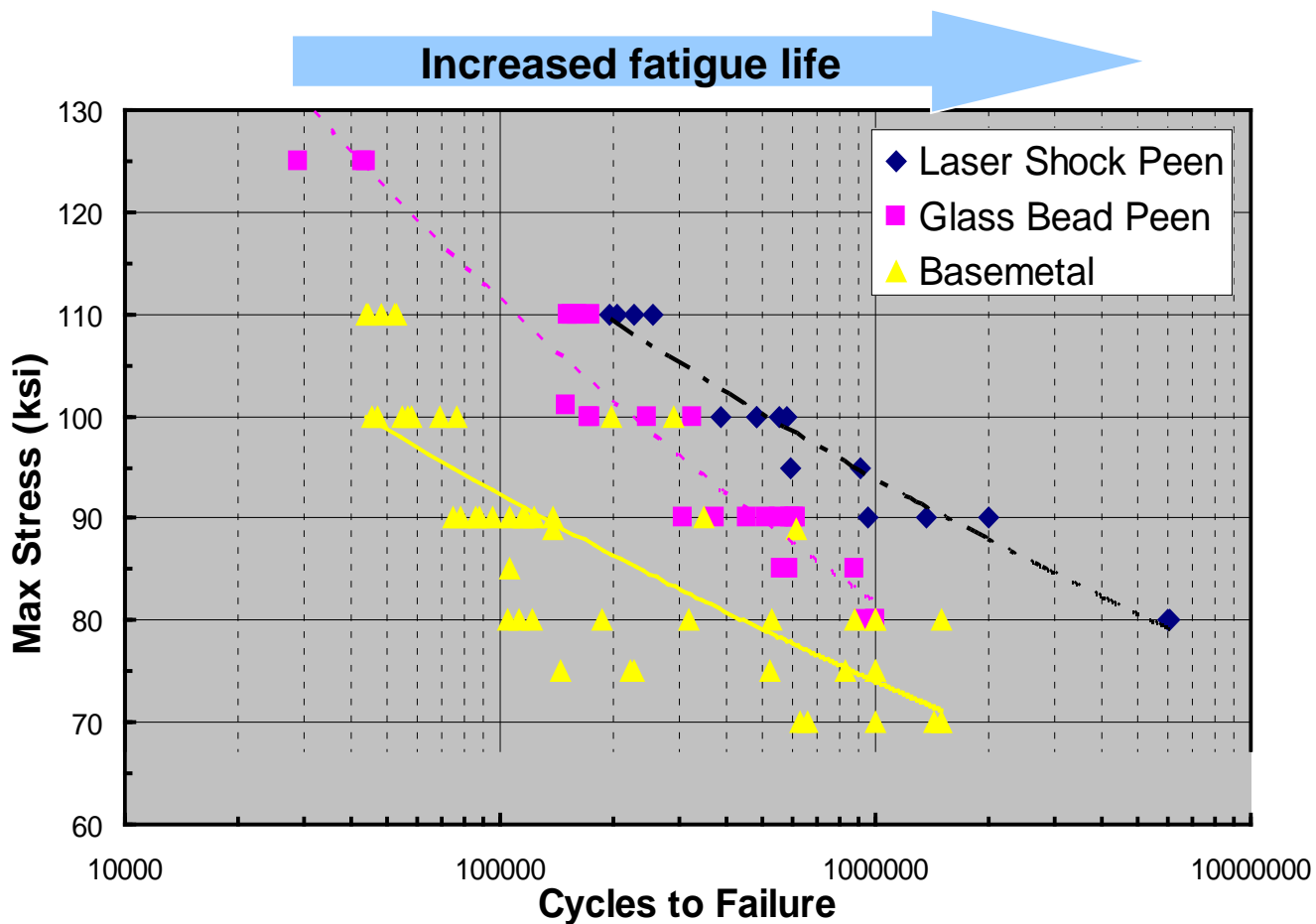
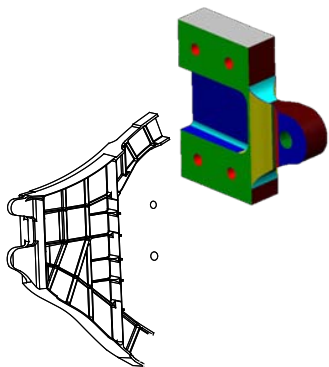
F-22 Mobile LSP Maturation



## Peening Fatigue Life Benefit EMD “Flat Bar” Data

### EMD coupon tests:

- Validated GBP benefit
- Suggests LSP would offer additional improvement
- Aircraft life extension pending DO-30 lug data and frame test validation

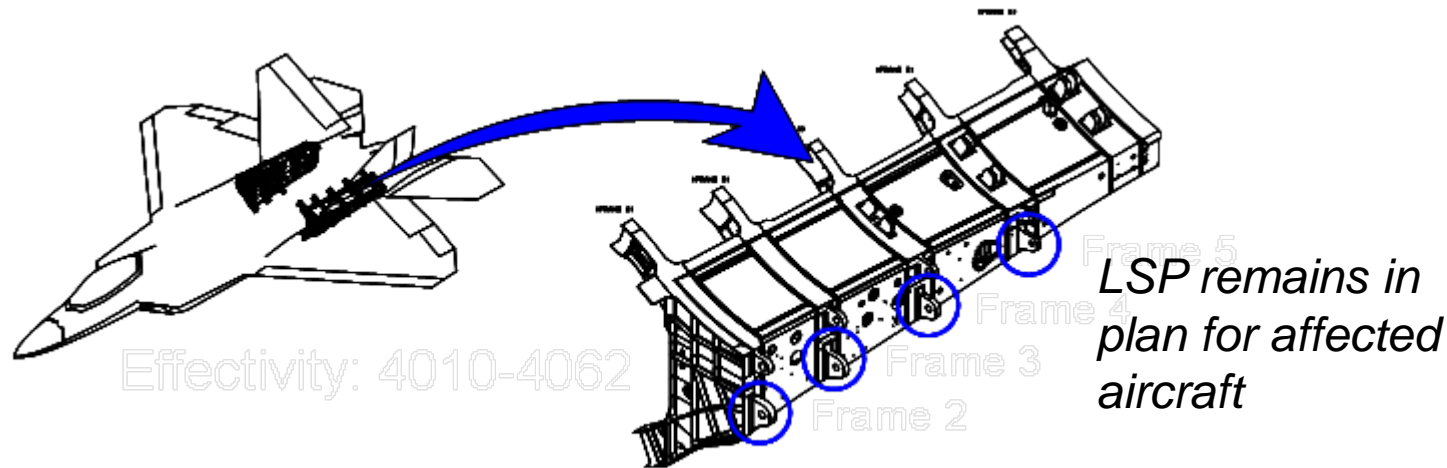


# F-22 Raptor Structural Retrofit

F-22 Mobile LSP Maturation



- **DO-30 Ph1 lug element tests generated positive results:**
  - “At-risk” GBP application proving effective for F-22 application
  - LSP offers a significant re-peening benefit to both life and crack growth



- LSP requires significantly more time, equipment, and facilitization than GBP
- “Mobile peening” equipment developed, but had not yet been implemented
- FASTeR LSP Maturation project envisioned to retire technical risk
  - Supplier: Metal Improvement Company (MIC – Livermore CA)
  - Purpose: Adapt existing LSP capability to the F-22 Mod Site

# Glass Bead Peen Application (SRP1)

F-22 Mobile LSP Maturation



- **GBP Process:** Pressurized air propels glass beads onto part surface creating a compressive surface layer with increased fatigue durability
  - *MIC can perform the GBP in any adequately equipped bay*
  - *Bay requirements are benign – containment tent easily erected*
  - *Flexibility exists for redirection to any such bay upon arrival*



**SRP1 Retrofit of Wing Attach Lugs**

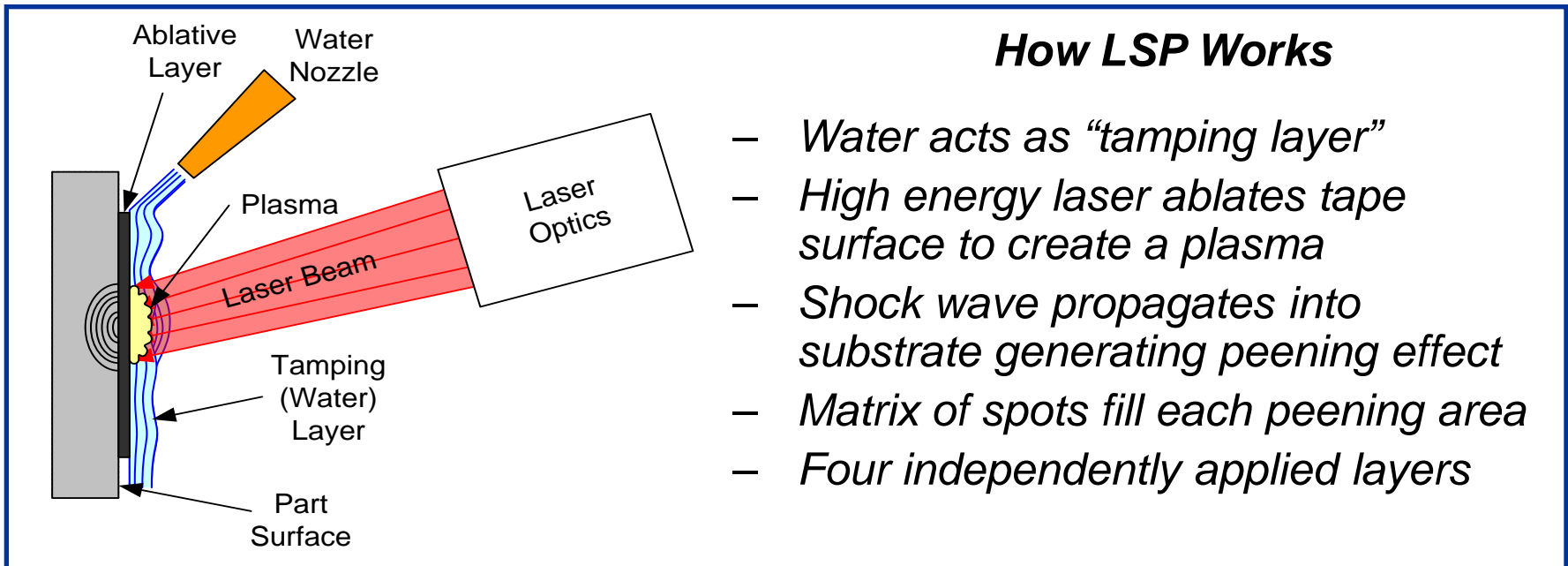
*In contrast, LSP is a much more involved operation*

# LSP Attributes and Challenges

F-22 Mobile LSP Maturation



- **Original Factory Process:** Parts and water robotically manipulated in front of stationary beam in factory work cell (engine fan blades, hubs etc.)
  - MIC later developed in-factory moveable beam/stationary part approach



- **Transition to “Mobile LSP” adds even more complexity**
  - Truck mounted laser feeds robot through optically tuned “light pipes”
  - Robot then redirects laser within containment tent (~5000 shots per jet)
  - Must reliably deliver the same peening effect as the test program



# LSP Attributes and Challenges: GBP to LSP is an Extensive Transition

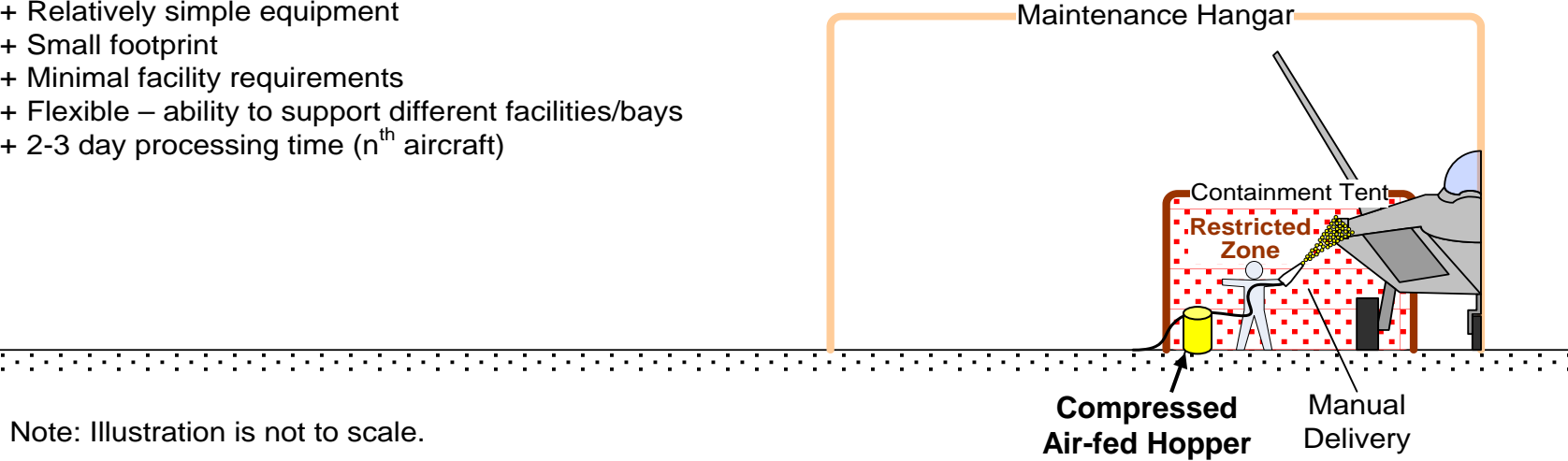
F-22 Mobile LSP Maturation



DO-024

GBP Setup

- + Relatively simple equipment
- + Small footprint
- + Minimal facility requirements
- + Flexible – ability to support different facilities/bays
- + 2-3 day processing time ( $n^{\text{th}}$  aircraft)

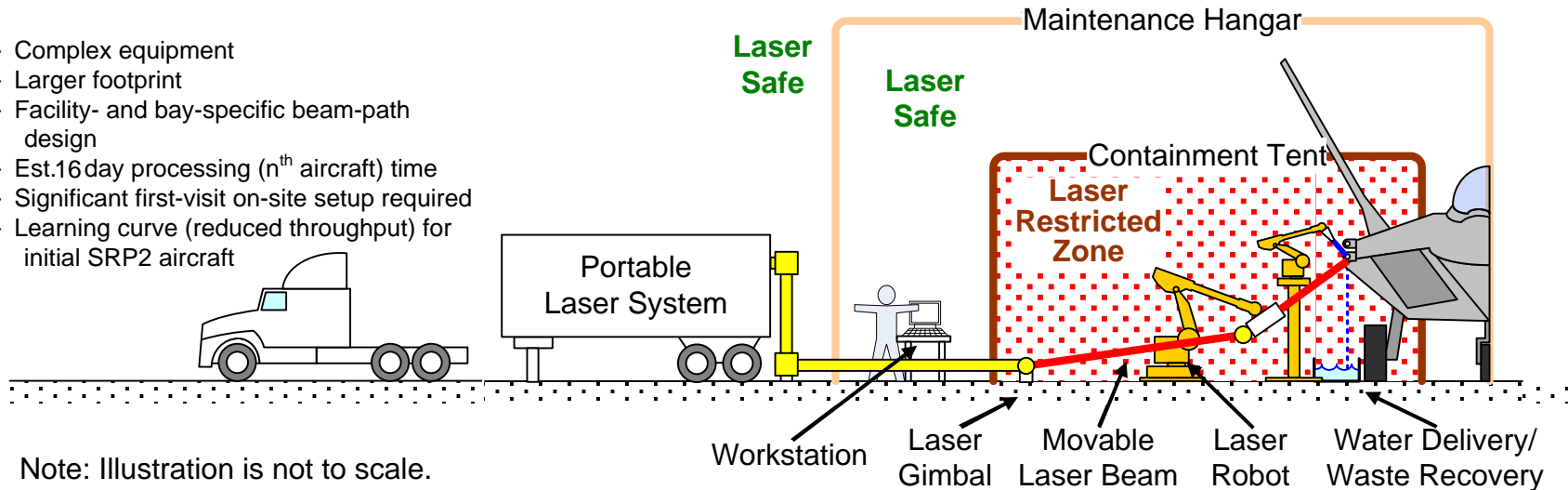


Note: Illustration is not to scale.

FASTER (SRP2)

LSP Setup

- + Complex equipment
- + Larger footprint
- + Facility- and bay-specific beam-path design
- + Est. 16 day processing ( $n^{\text{th}}$  aircraft) time
- + Significant first-visit on-site setup required
- + Learning curve (reduced throughput) for initial SRP2 aircraft



Note: Illustration is not to scale.

# LSP Attributes and Challenges: How Can This Transition Be Made at Low Risk?

F-22 Mobile LSP Maturation



- **Desired Attributes:**
  - *Minimal safety risks to personnel or aircraft*
  - *Rapid and reliable processing*
  - *Ensure flexibility to adapt to mod-line perturbations*
- **Challenges Foreseen (principle examples):**
  - **Safety:** *Laser hazard and robot incursion risk with each move*
  - **LSP Process:** *Involves thousands of robot moves and non-value added tasks such as mate / de-mate of containment tents*
  - **Depot Approach:** *“Tuned” optics delivery requires bay-specific designs and has non-value added tasks such as set-up / tear-down of optics*
- **Resolution Efforts Undertaken:**
  - *Implement reliable containment of laser and prevent robot incursions*
  - *“Lean out” LSP process to reduce cycle time – maintaining precision*
  - *“Lean out” Depot approach – maintaining schedule flexibility*

**Technology maturation effort necessary to adapt existing  
LSP capability to F-22 at acceptable (low) risk**

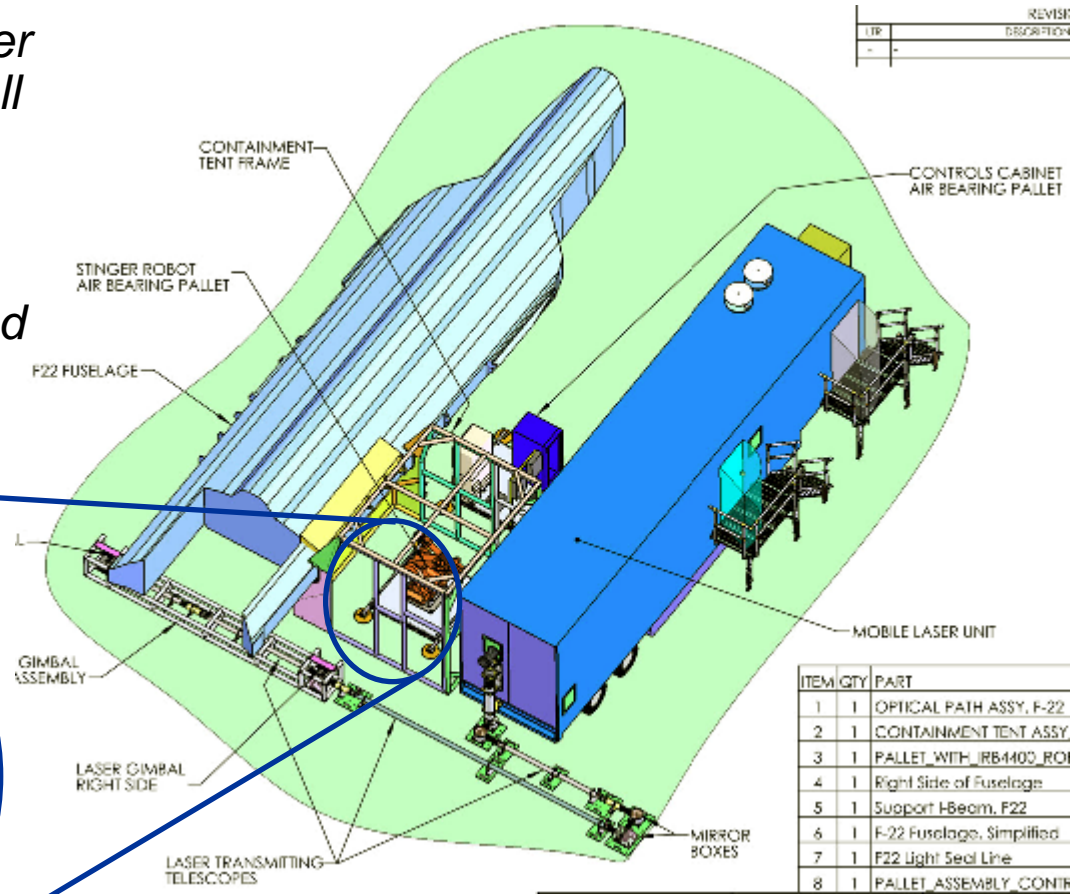
# LSP Maturation Program – Safety

F-22 Mobile LSP Maturation



## Personnel Safety Features

- Light pipe safely contains laser delivery from truck to work cell
- LHS/RHS local containment tents seal to aircraft
- Access interlocks shut down system if work cell is breached



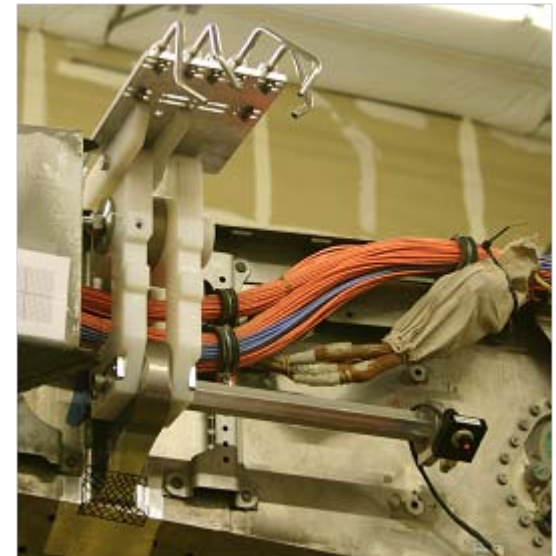
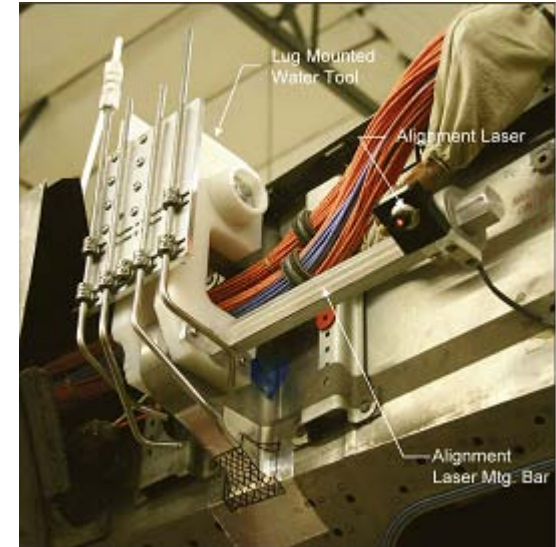
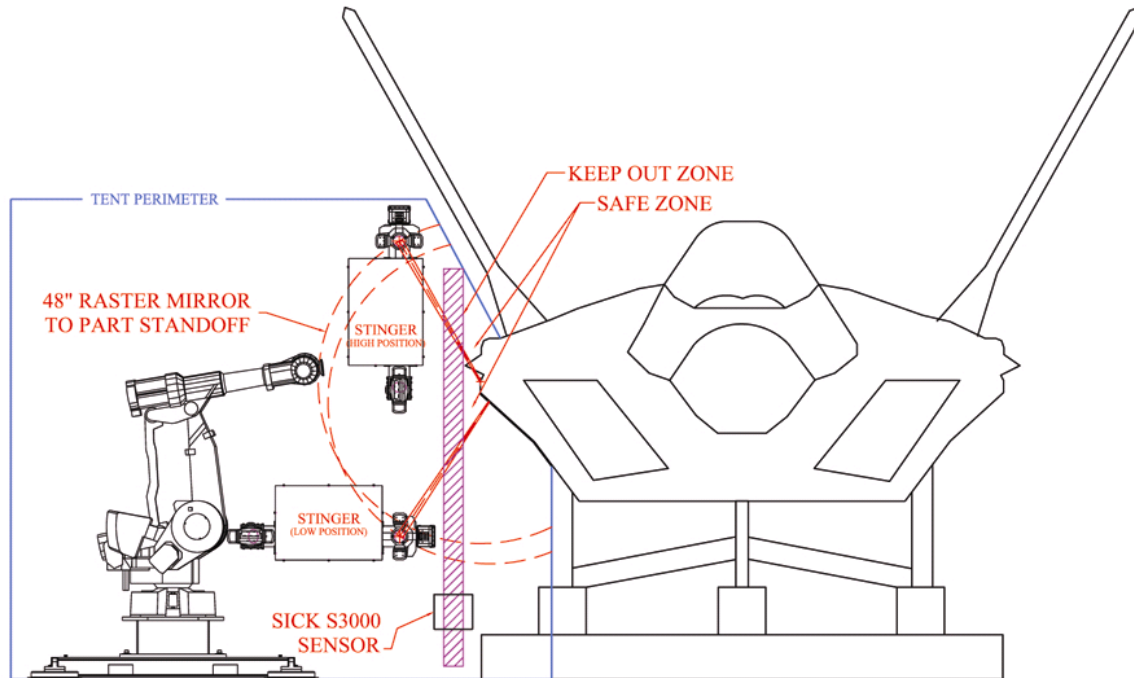
# LSP Maturation Program – Safety

F-22 Mobile LSP Maturation



- **Aircraft Safety Features**

- Increased laser robot stand-off distance and reduced required moves - discussed later
- Independent light curtain integrated into system
- Water robot replaced with fixed plumbing – eliminates “close-standoff” robot moves



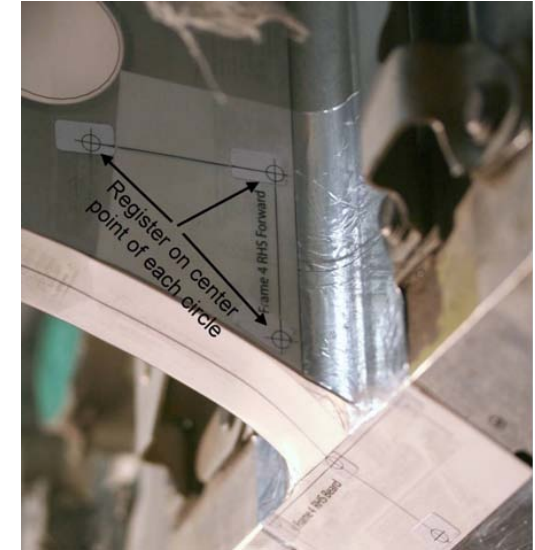
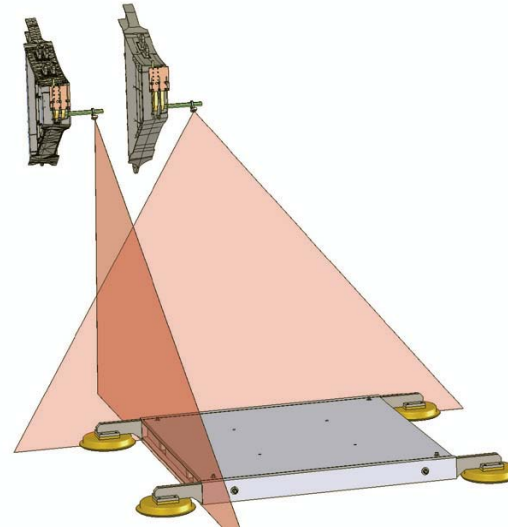
# LSP Maturation Program – Lean Process

F-22 Mobile LSP Maturation



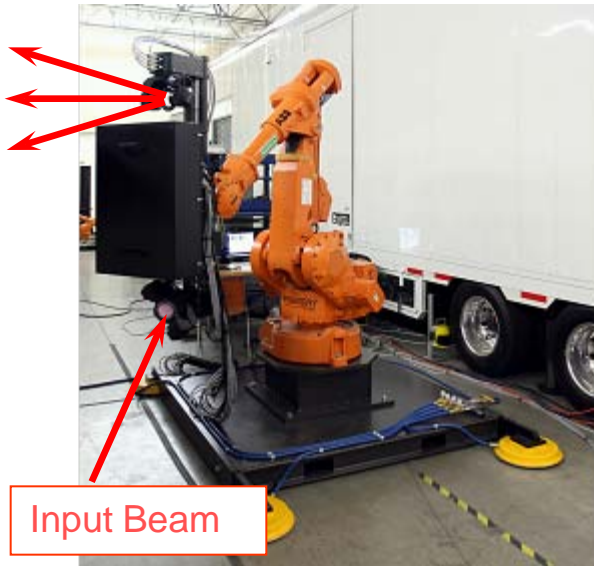
- **Set-up Time Minimized**

- *Water robot eliminated*
- *Laser-based pallet positioning developed*
- *Mylar overlays provide fiducials for robot-to-aircraft registration*



- **Implemented Innovative “Raster Head”**

- *Adapted from MIC system at BCA Fredrickson*
- *Gimbal redirects a highly configurable beam to each group of shots*
  - *Robot manipulations reduced 50X*
  - *Enables common peening “philosophy”*
- *Extra “reach” enables single pallet position*

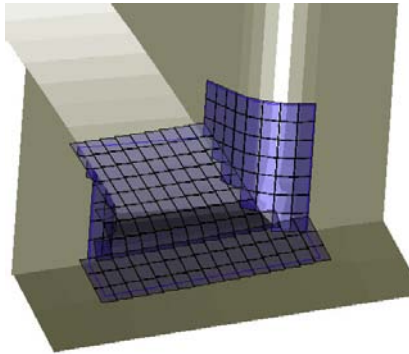


# LSP Maturation Program – Lean Process

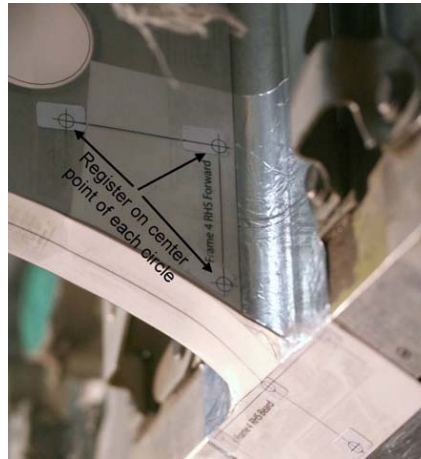
F-22 Mobile LSP Maturation



1. Spot Pattern Design



2. Register and set-up at Lug



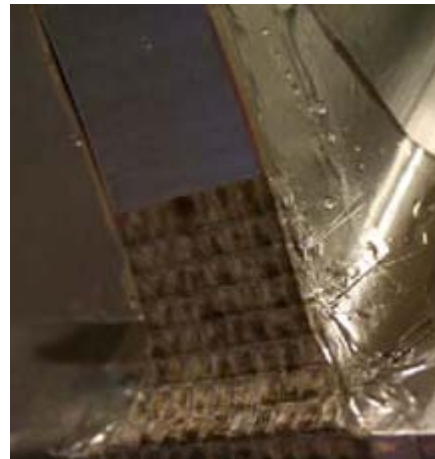
3. Witness Paper Check (Adjust for Aircraft OML Variations as Necessary)



Process Has Now Been Repeatedly Demonstrated



5. Final Result is only subtly visible



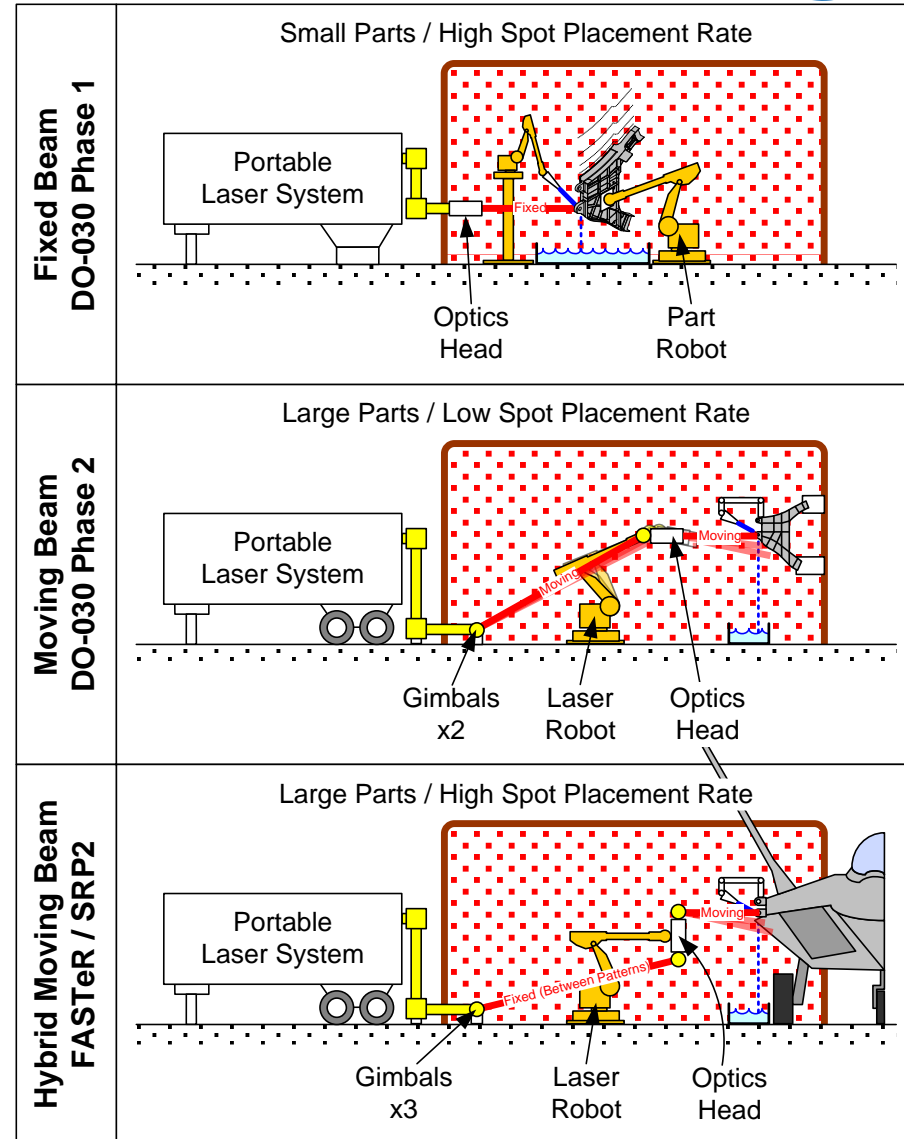
4. QA Peened Tape

# LSP Maturation Program Process Evolution Summary

F-22 Mobile LSP Maturation



- **Prior Art was Fixed Beam Delivery**
  - Proven factory production
  - Limited to small parts
  - Used on EMD test coupons, DO-30 lugs and early trial frames
- **Adopted MIC's Movable Beam Approach**
  - Can process stationary targets
  - Water robot deleted
  - Robot must manipulate to each of 5000 peening spots per A/C (long cycle time)
  - Used for DO-30 trial frames
- **Raster Head Integrated in LSP Maturation**
  - Robot only manipulated to each of 100 “groups” of ~50 shots (for all 4 layers)
  - Used on 4001 fuselage and planned for DO-30 test frames
  - Enables common peening “philosophy”





## Agenda

Purpose: Provide an overview of the requirement, challenges, and implementation of LSP on the F-22

F-22 Raptor Structural Retrofit Requirement

Glass Bead Peen Application (SRP1)

LSP Attributes and Challenges

LSP Maturation Program (LSPM)

[Demonstration Video](#)

→ Implementation at Depot (SRP2)

Summary of Lessons Learned

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# LSP Maturation Program – Lean Depot

F-22 Mobile LSP Maturation



- **Starting Point for Depot Implementation:**
  - Previously described capability as depicted below at MIC-Livermore
  - Depot approach as was used for Glass Bead Peening in SRP1
    - Multiple aircraft depots
    - Peening capability taken to wherever the jet is being worked

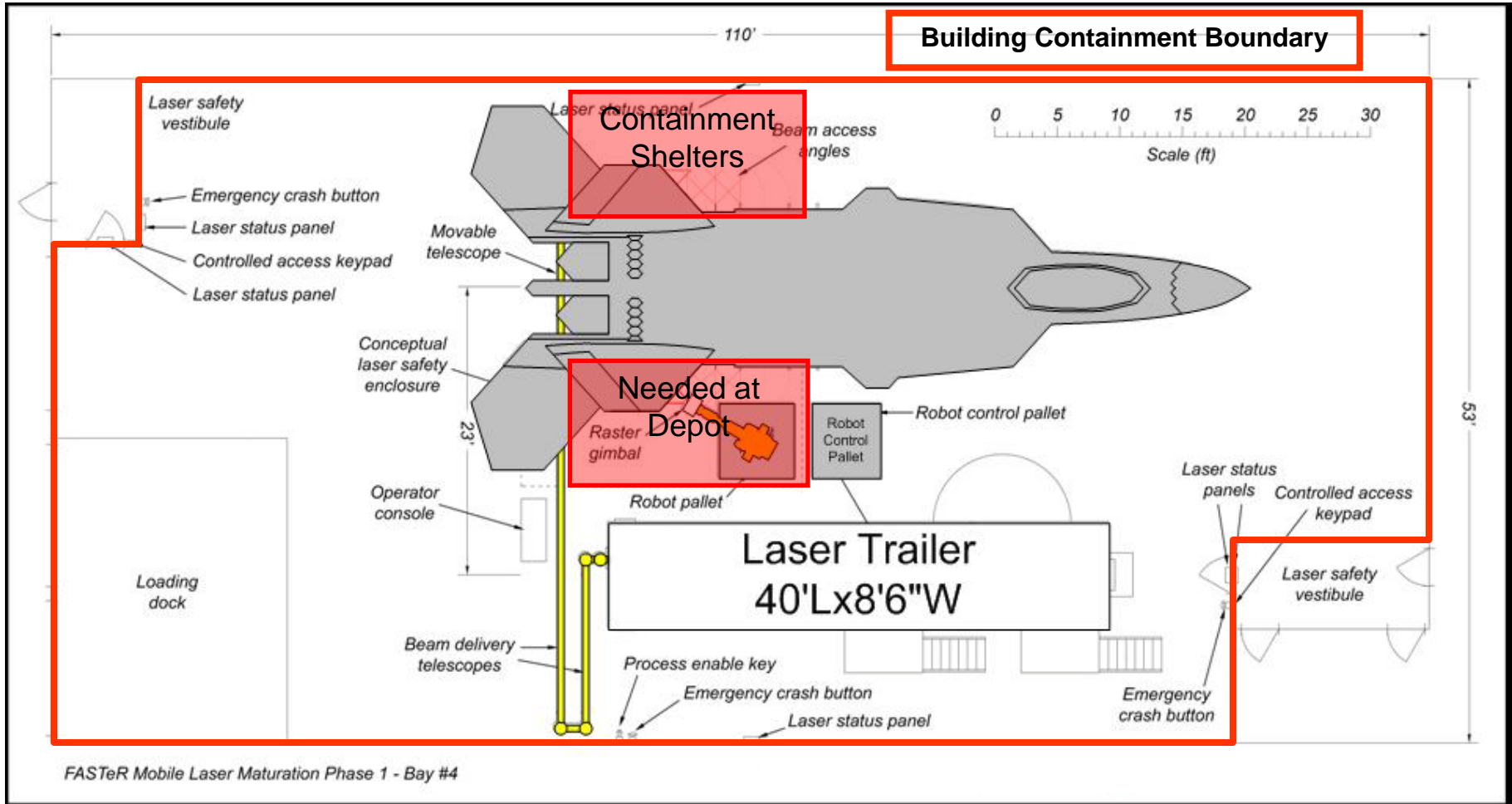


# LSP Maturation Program – Lean Depot

F-22 Mobile LSP Maturation

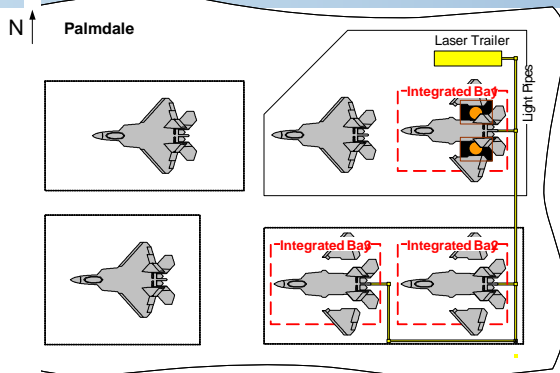


Initial Concept Similar to GBP: Bring the system to wherever the aircraft resides



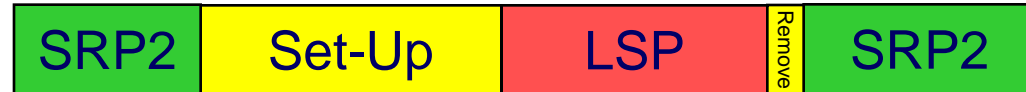
# LSP Maturation Program – Lean Depot

F-22 Mobile LSP Maturation



**Take LSP to Each Aircraft - Synonymous with GBP**

Wing R&I, Transport & set up full optics and tents at each event



16 M-Days

**Relocate Entire Aircraft into Dedicated LSP Bay at Each Mod Site**

Wing R&I, Transport Laser & set up partial system at each event



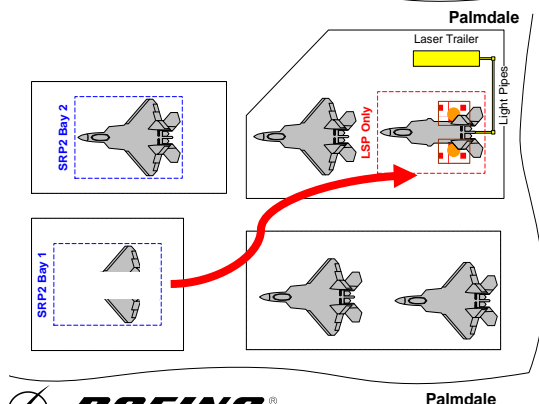
12 M-Days

**Relocate Fuselages Only into Dedicated LSP Bay at Palmdale**

Connect/set up partial system at each event



8 M-Days

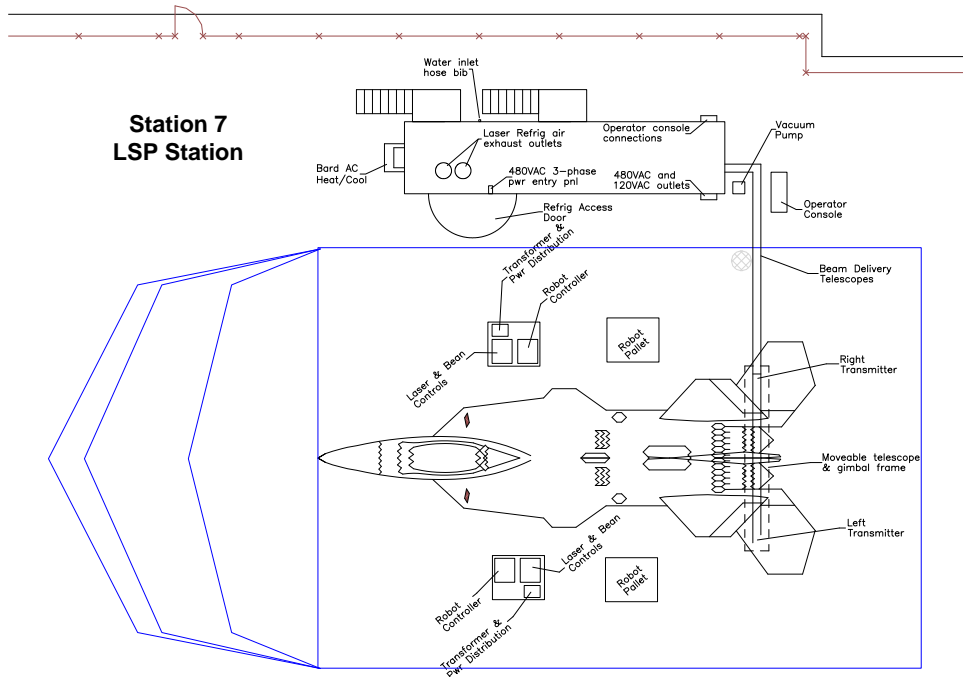


# LSP Maturation Program – Lean Depot

F-22 Mobile LSP Maturation



- **Efficiency of delivering fuselages paved the way for single site operations**
  - All LSP jets re-routed to Palmdale
  - Enabled deletion of local tents in favor of full fuselage containment
  - Additional reduction from 8 to ~7 M-Days by eliminating tent mate/de-mate



# LSP Maturation Program – Lean Depot

F-22 Mobile LSP Maturation



- **Leaning Out the Depot Approach Reduces.....**
  - **Cost Risk:**
    - Enables “LSP Services” procurement in lieu of per-unit contracting
    - Saves \$1M NRE & \$3M Recurring costs
  - **Technical Risk:**
    - Eliminates laser transportation between Palmdale and Hill AFB
    - Eliminates set up / tear down damage
  - **Schedule Risk:**
    - LSP bay cycle time reduced from 16 to ~7 M-Days
    - This efficiency reduces the calendar day duty cycle in the LSP bay to only 50% (as a two shift operation)
    - Resulting “Down Time” accommodates early or late inductions

# Summary of Lessons Learned

F-22 Mobile LSP Maturation



- **LSP processing**
  - LSP is an effective tool for addressing fatigue life shortfalls
  - Maturation was needed to adapt LSP for Depot use
  - Current capability is on track for implementation in 2011
- **Depot Approach:**
  - Not a business-as-usual retrofit
  - Advance coordination is critical
  - Coordination logistics must be addressed (safety, environmental, security)

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## Agenda Review

- F-22 Raptor Structural Retrofit Requirement
- Glass Bead Peen Application (SRP1)
- LSP Attributes and Challenges
- LSP Maturation Program (LSPM)
- Implementation at Depot (SRP2)
- Summary of Lessons Learned

### Acknowledgements:

- MIC Team for the commendable capabilities developed
- Morgan Osborne for his energetic assistance
- LM-Aero & F-22 Program Office for flexibility in this evolution

## Questions?

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