

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

2nd International Conference on Laser Peening
April, 2010



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

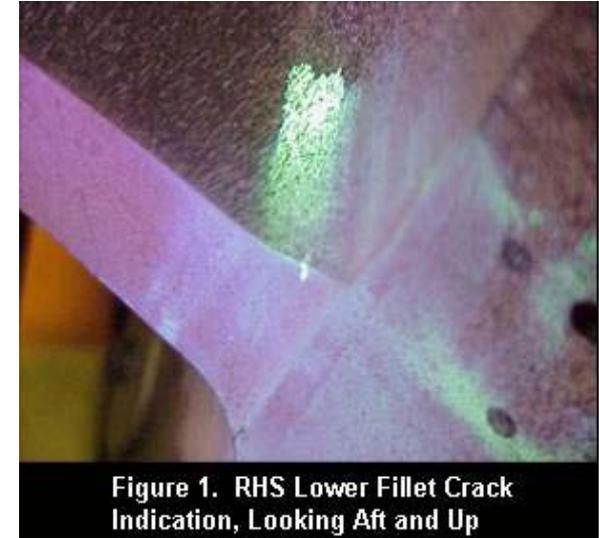
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F-22 Raptor Structural Retrofit

F-22 Mobile LSP Maturation

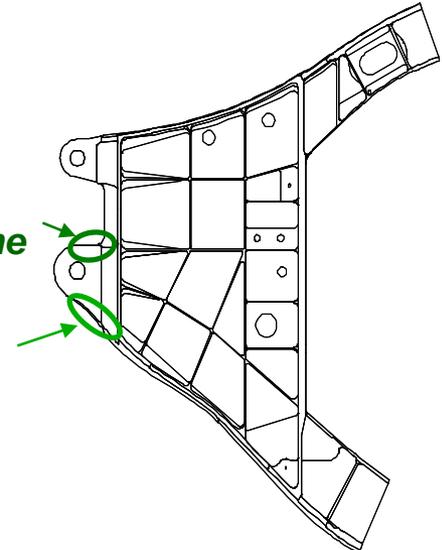


- **Reduced Risk of Fatigue Cracking at Lugs Desired**
 - Design adjustment applied to majority of fleet
 - Early aircraft were slated for life extension retrofit
- **Glass Bead Peening (GBP) implemented “at risk”**
 - Coupon test data suggested risk was low
 - Imparts beneficial surface compressive 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

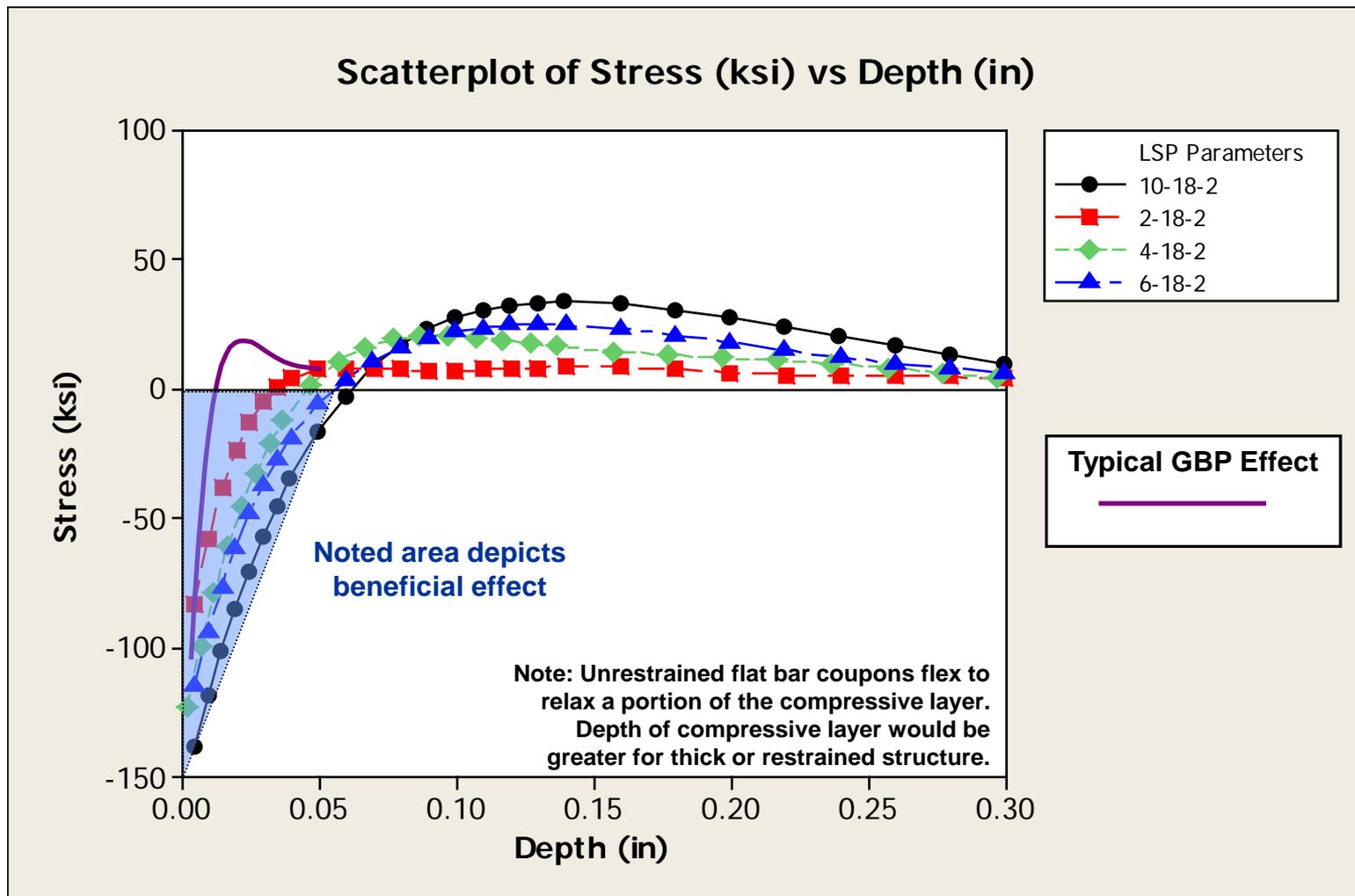


F-22 Raptor Structural Retrofit

F-22 Mobile LSP Maturation



LSP Surface Compressive Effect EMD "Flat Bar" Data



F-22 Raptor Structural Retrofit

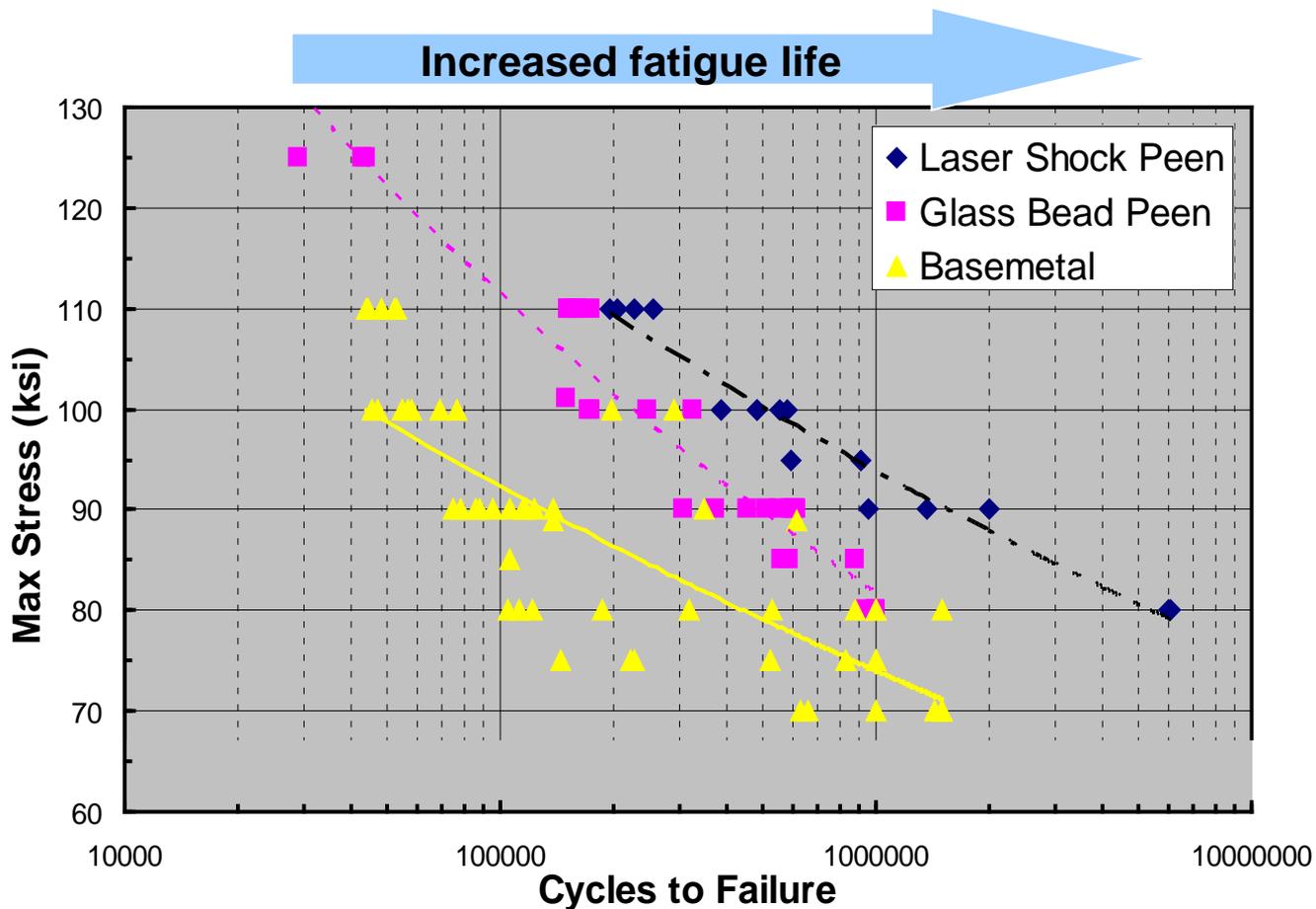
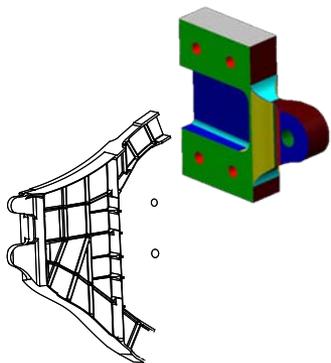
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Peening Fatigue Life Benefit EMD “Flat Bar” Data

EMD coupon tests:

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

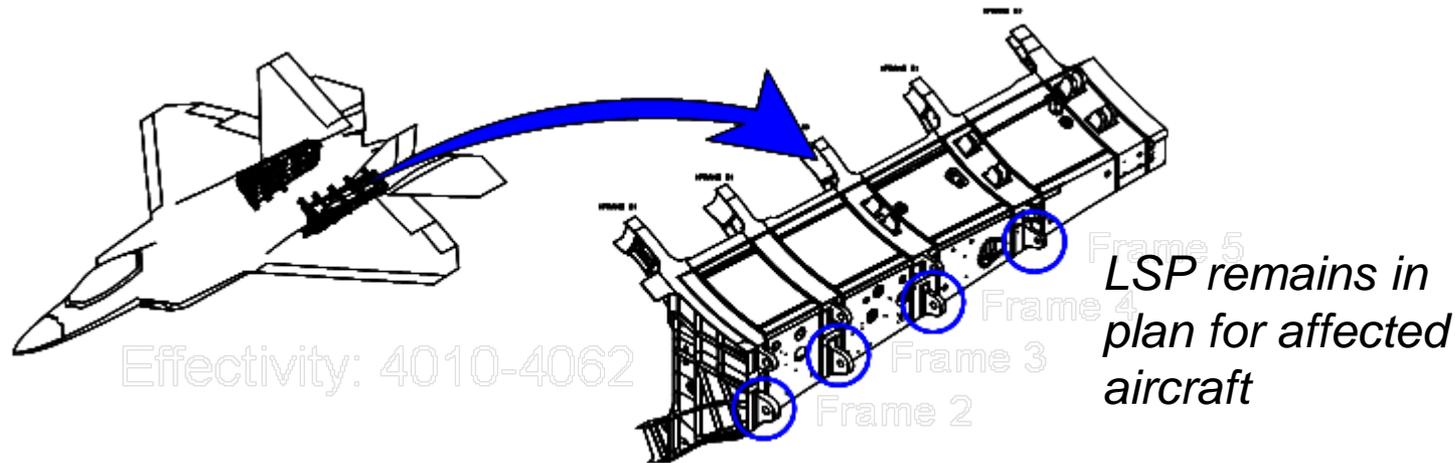


F-22 Raptor Structural Retrofit

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

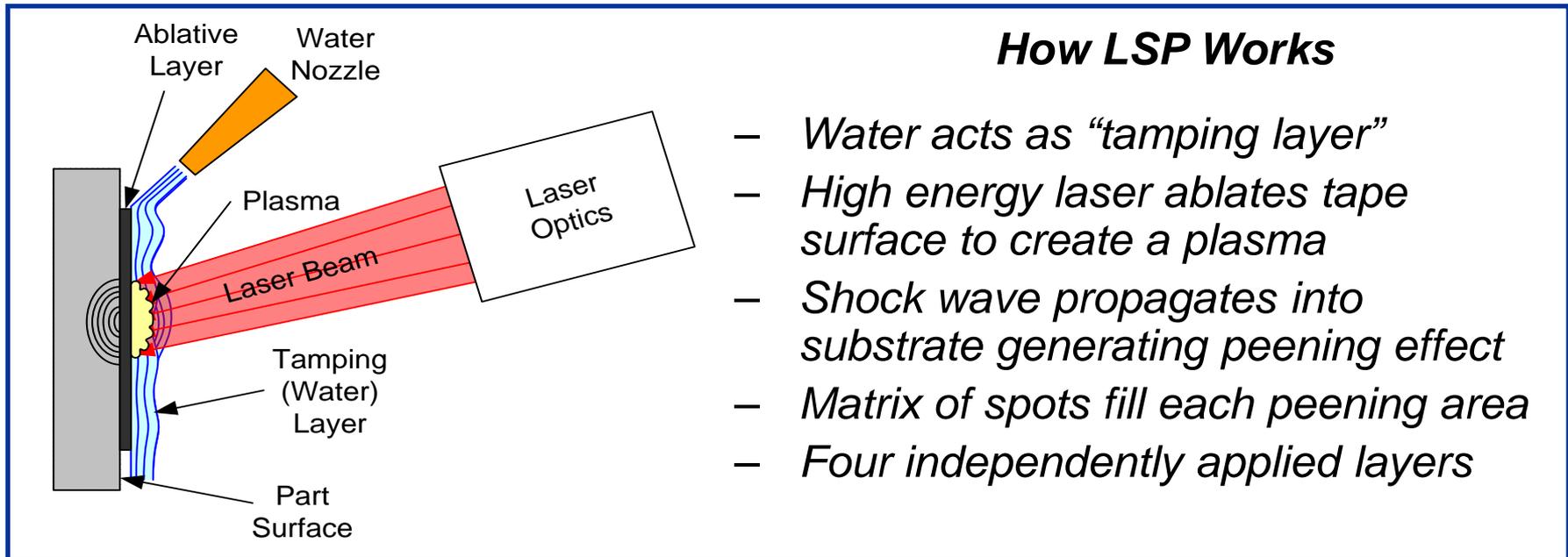
In contrast, LSP is a much more involved operation

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

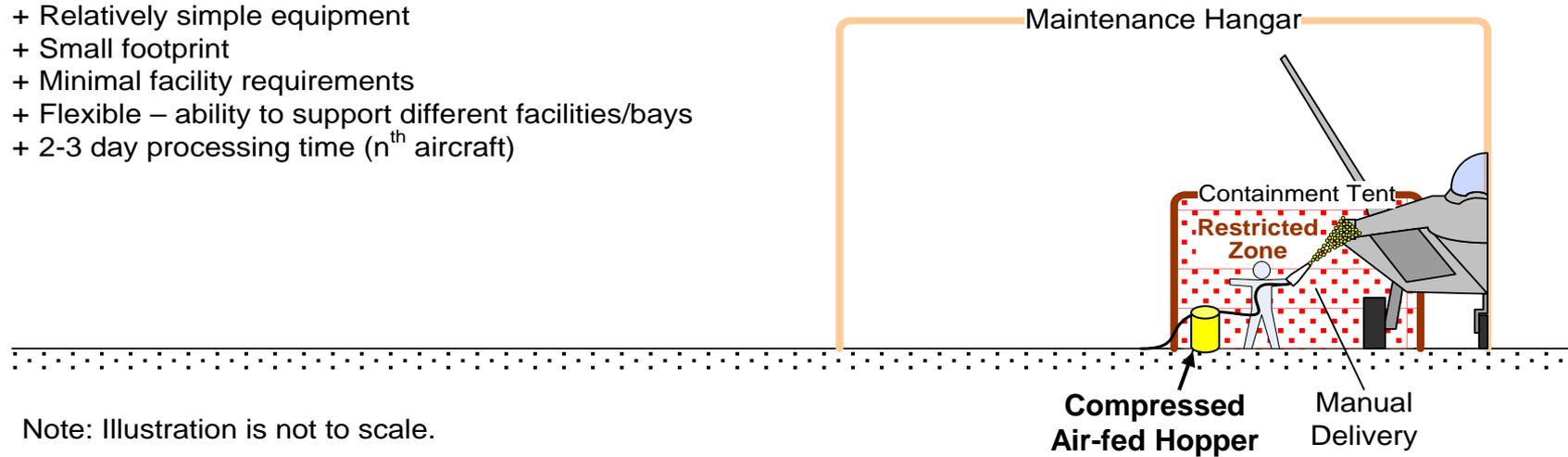
F-22 Mobile LSP Maturation



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^{th} aircraft)

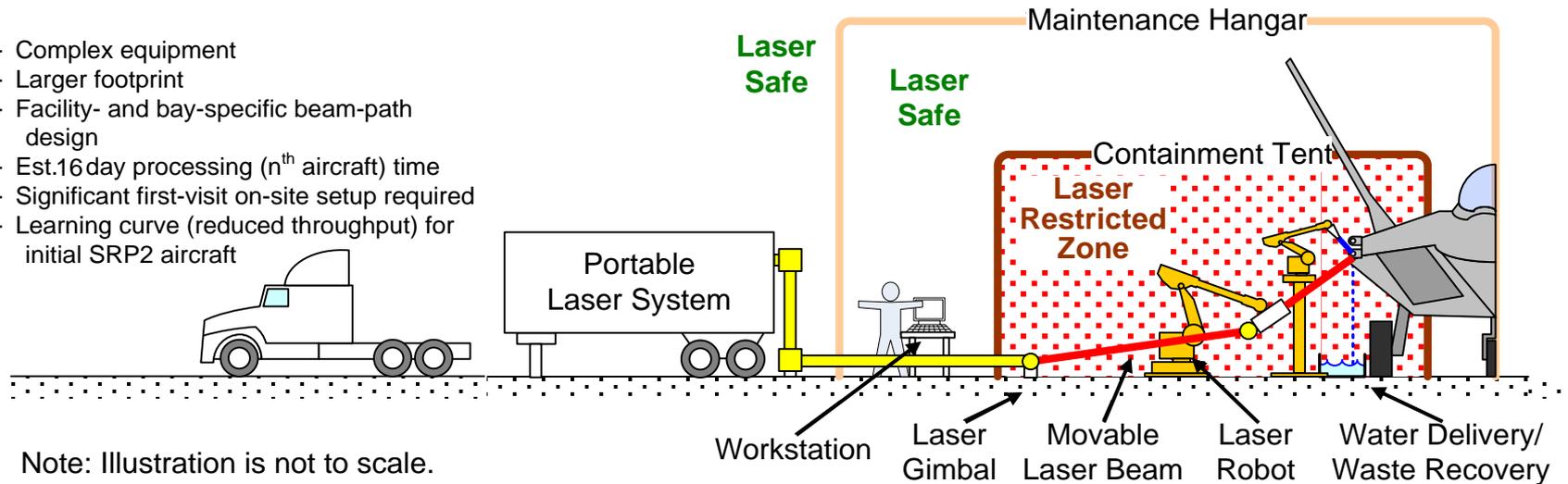


Note: Illustration is not to scale.

FASTER (SRP2)

LSP Setup

- + Complex equipment
- + Larger footprint
- + Facility- and bay-specific beam-path design
- + Est. 16 day processing (n^{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**

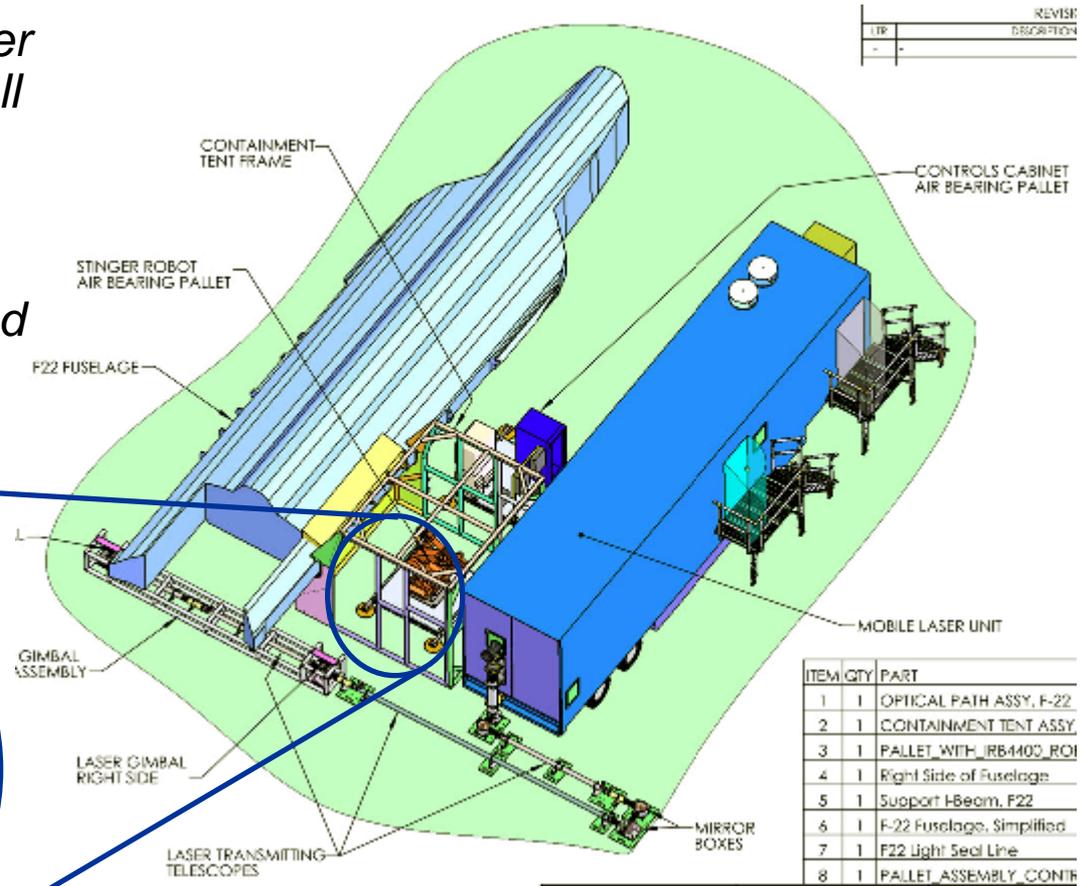
LSP Maturation Program – Safety

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



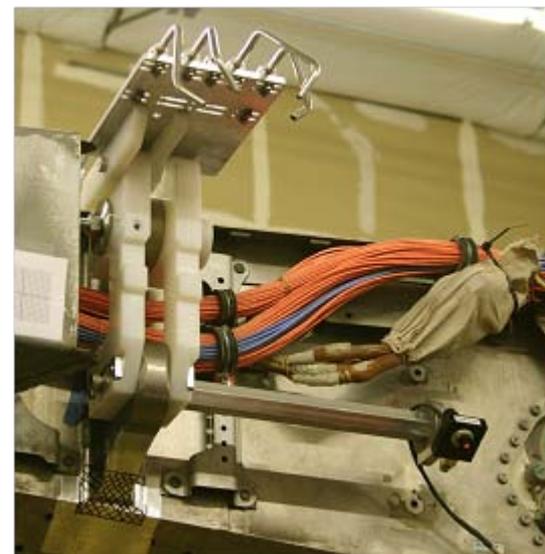
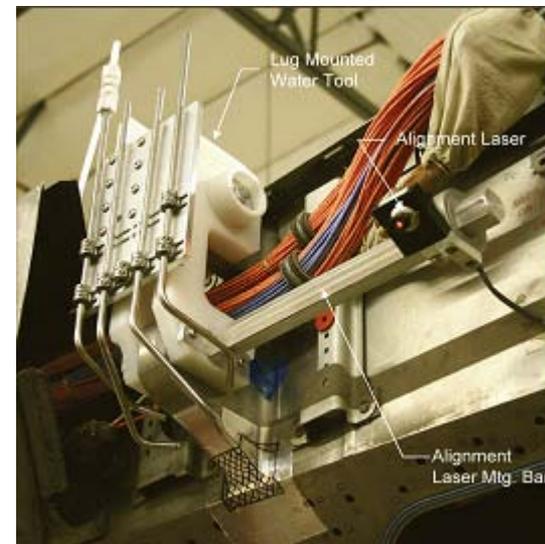
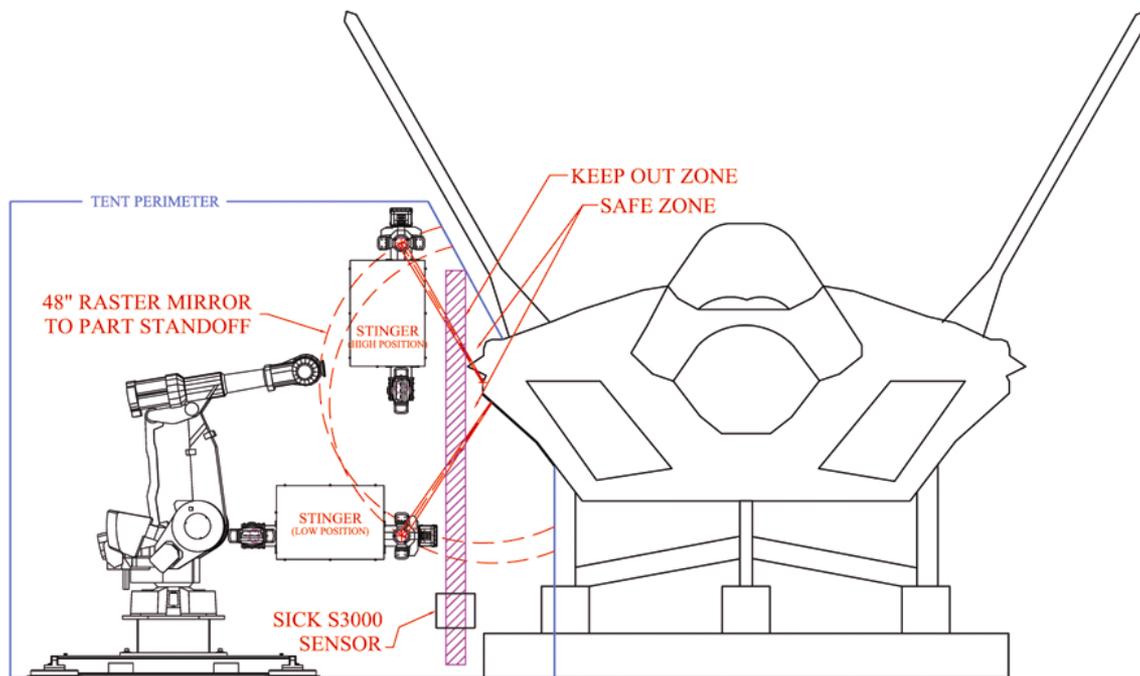
LSP Maturation Program – Safety

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



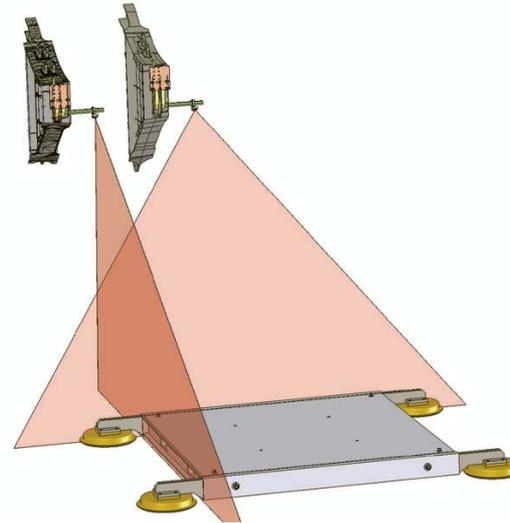
LSP Maturation Program – Lean Process

F-22 Mobile LSP Maturation



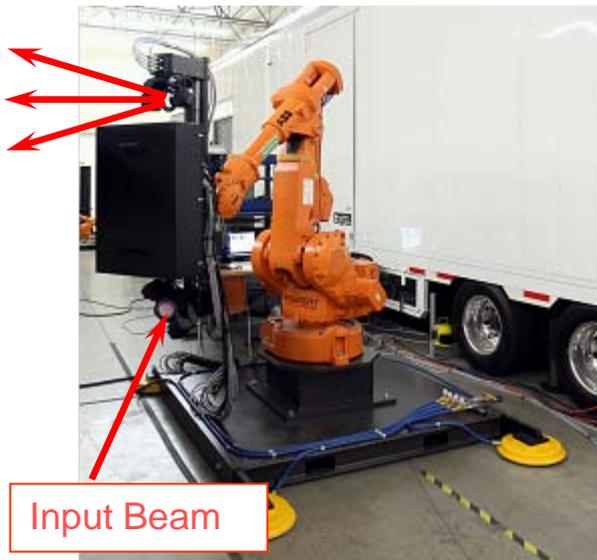
- **Set-up Time Minimized**

- *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*

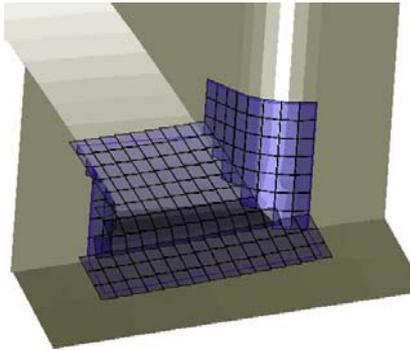


LSP Maturation Program – Lean Process

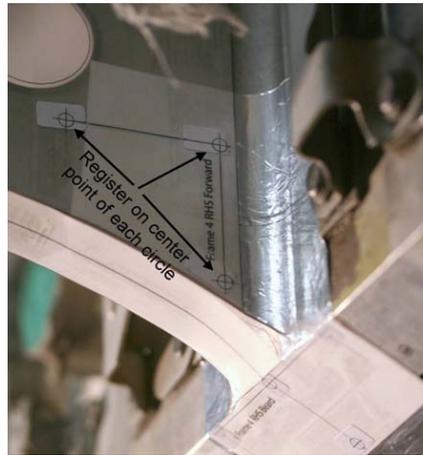
F-22 Mobile LSP Maturation



1. Spot Pattern Design



2. Register and set-up at Lug



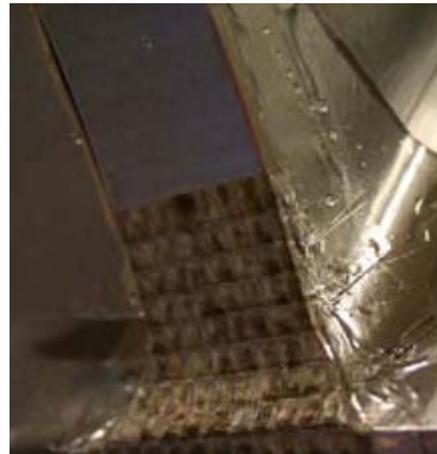
3. Witness Paper Check (Adjust for Aircraft OML Variations as Necessary)



Process Has Now Been Repeatedly Demonstrated



5. Final Result is only subtly visible



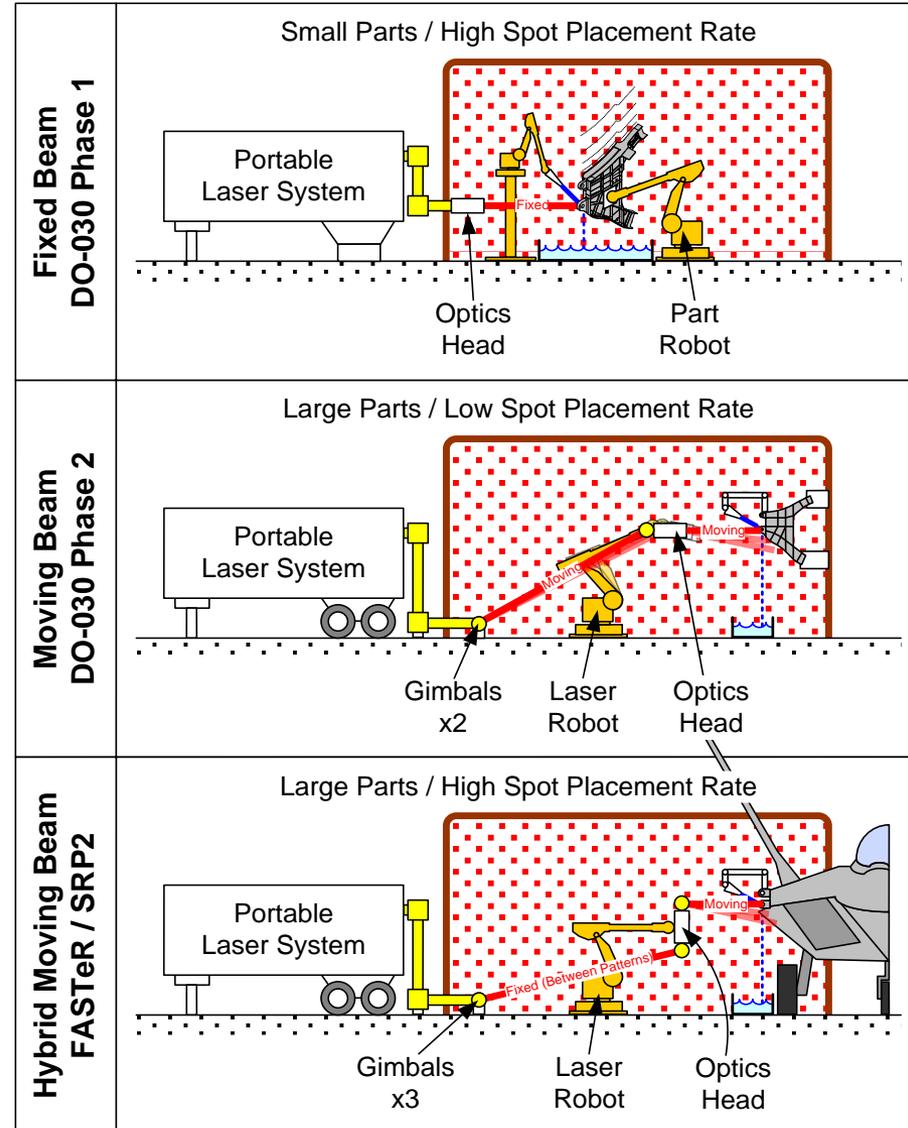
4. QA Peened Tape

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

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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

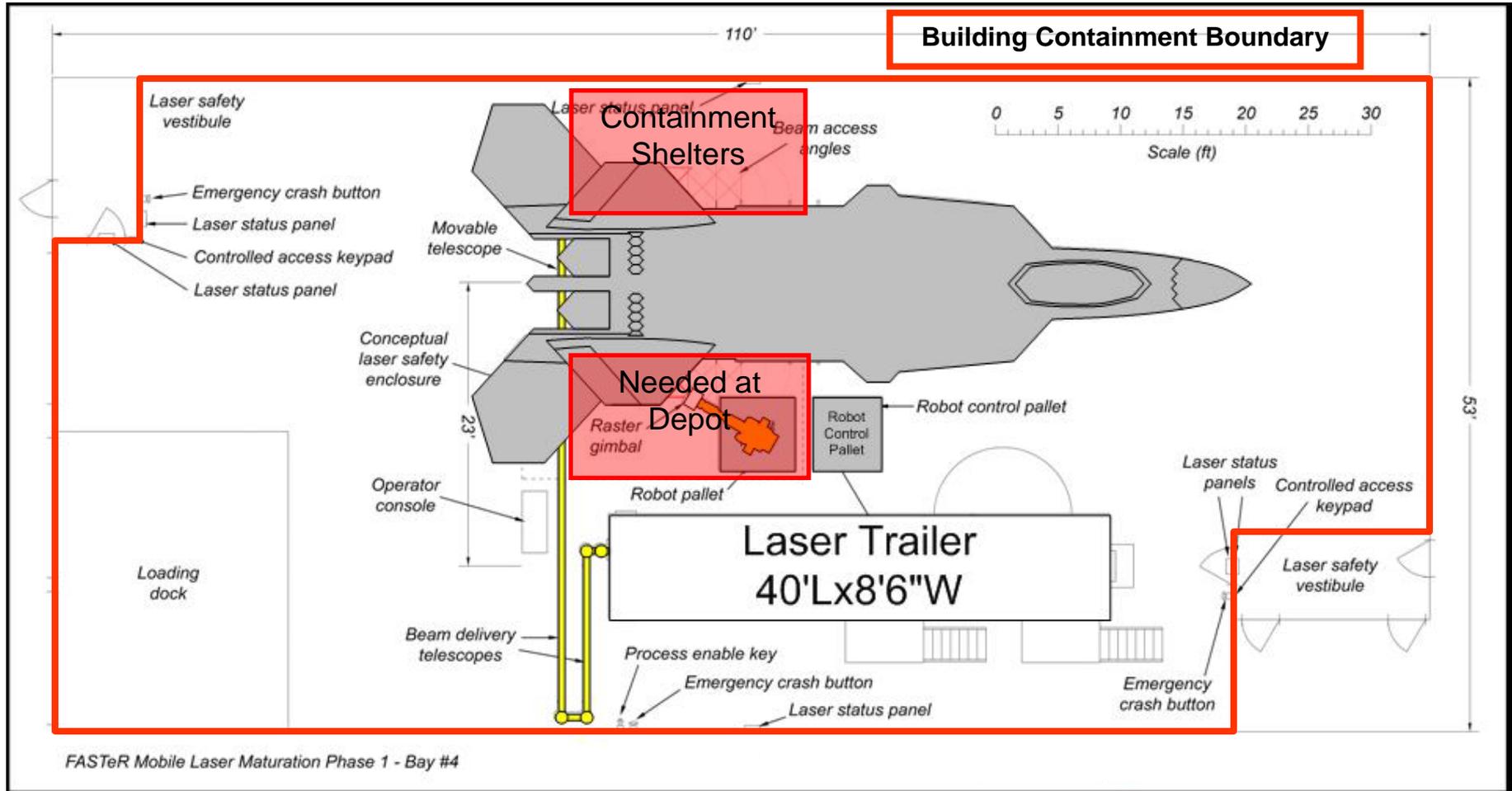


LSP Maturation Program – Lean Depot

F-22 Mobile LSP Maturation

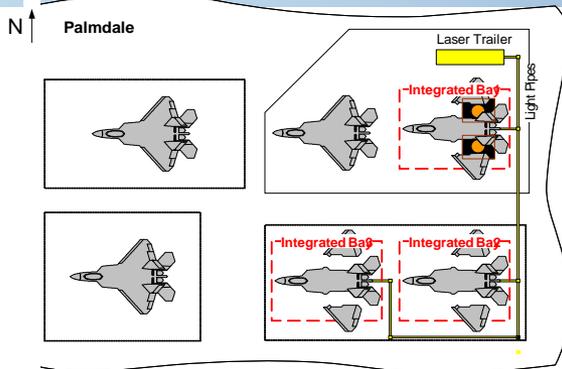


Initial Concept Similar to GBP: Bring the system to wherever the aircraft resides



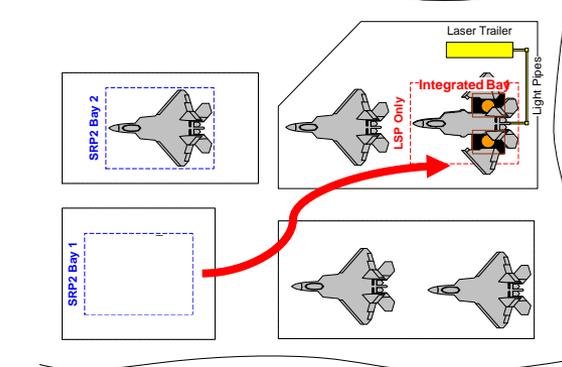
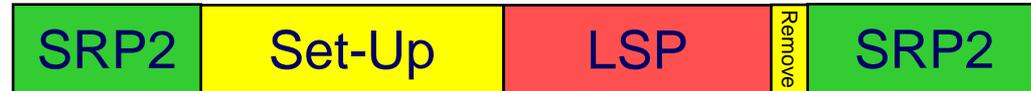
LSP Maturation Program – Lean Depot

F-22 Mobile LSP Maturation



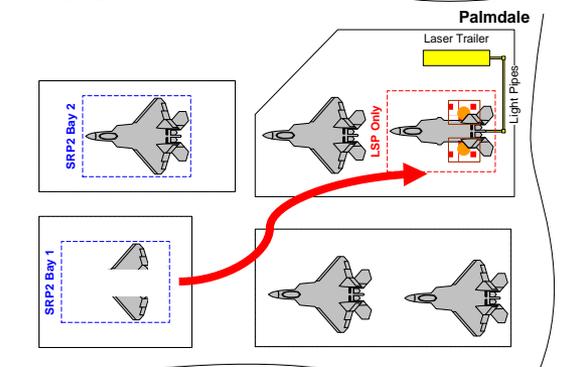
Take LSP to Each Aircraft - Synonymous with GBP

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



Relocate Entire Aircraft into Dedicated LSP Bay at Each Mod Site

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



Relocate Fuselages Only into Dedicated LSP Bay at Palmdale

Connect/set up partial system at each event



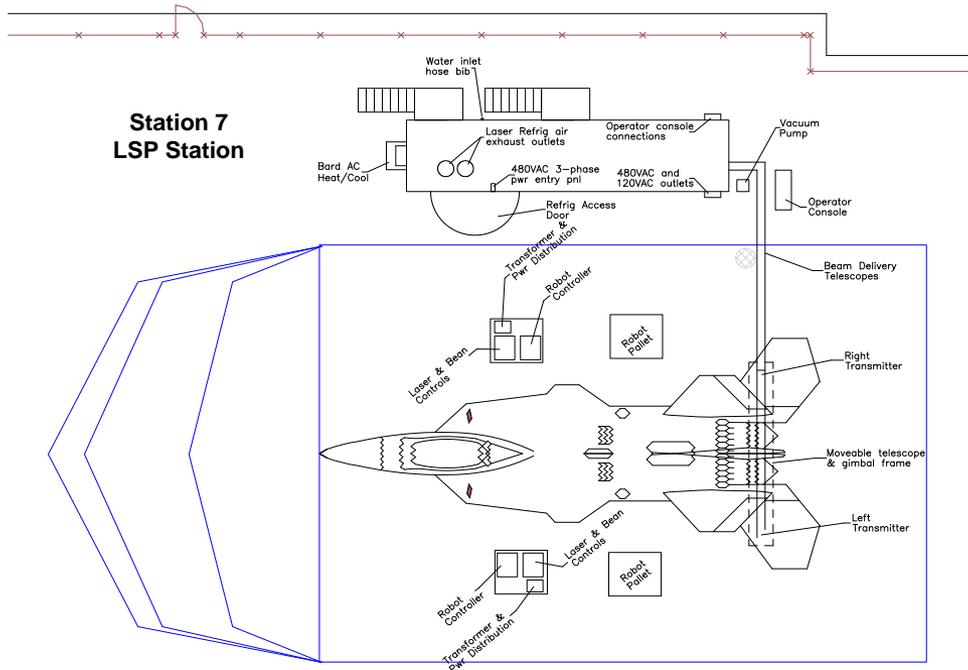
Palmdale

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

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- LSP Attributes and Challenges
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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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