

Laser **E**ngineered **N**et **S**haping (*LENSTM*)

Phase I Project Review & New Project Ideas Workshop

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PROJECT S.O.W.s - PRESENTATION TOPICS



S.O.W. LENS Manufacturer - Training - Software Development

Dave Keicher - Vice President / Chief Technology Officer

Presentation Topics: LENS Process Overview
LENS Benefits



S.O.W. DoD Organic Depot LENS Repair Validation Site

Chuck Gunnels - Materials Engineer * Weapons Systems & Lab Division

Presentation Topics: AGT-1500 Engine Part Repair Case Studies
LENS Part Reclamation Cost Savings



S.O.W. Service Provider - Training - Process Development

Tom McDonald - Vice President * Advanced Technology Group

Presentation Topics: LENS Process Development
LENS Phase I Application Assessment
LENS Phase I Summary - CTMA Phase II & Beyond

PROJECT'S PRIMARY GOAL: VALIDATE ANAD ESTIMATED COST SAVINGS



ITEM #1

Third (3rd) Stage Turbine Rotor



ITEM #2

Fourth (4th) Stage Turbine Rotor



ITEM #3

Second (2nd) Stage Nozzle



ITEM #4

Compressor Stator 1st L.P.

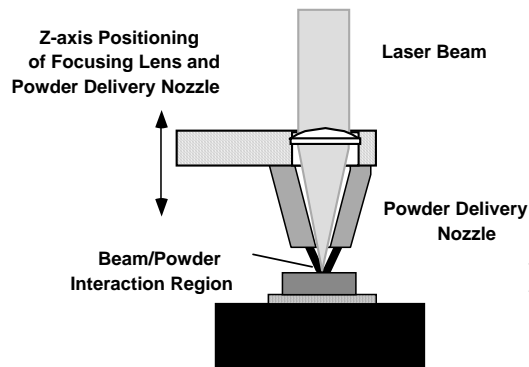
LASER ENGINEERED NET SHAPING (LENS) - ESTIMATED PER YEAR COST SAVINGS

ITEM	PART	MATERIAL	PART NUMBER	NEW PART COST	ESTIMATED REPAIR COST	SAVINGS PER PART	PARTS REPAIRED PER YEAR	SAVINGS PER YEAR
1	Third (3rd) Stage Turbine Rotor	M3610C/Inconel 713LC	12271565	\$ 8,297	\$ 2,000	\$ 6,297	230	\$ 1,448,416
2	Fourth (4th) Stage Turbine Rotor	M3610C/Inconel 713LC	12281566	\$ 5,485	\$ 2,000	\$ 3,485	230	\$ 801,529
3	Second (2nd) Stage Nozzle	M3602/Inconel 713C	12286886	\$ 6,032	\$ 2,250	\$ 3,782	600	\$ 2,269,140
4	Compressor Stators (H.P. and L.P.)							
	1st L.P.	AMS 5510/321 Stainless	12302430	\$ 910	\$ 300	\$ 610	175	\$ 106,759
	2nd L.P.	AMS 5510/321 Stainless	12286149	\$ 1,170	\$ 300	\$ 870	175	\$ 152,264
	3rd L.P.	AMS 5510/321 Stainless	12302480	\$ 610	\$ 300	\$ 310	175	\$ 54,304
	4th L.P.	AMS 5510/321 Stainless	12286161	\$ 611	\$ 300	\$ 311	175	\$ 54,495
	5th L.P.	AMS 5510/321 Stainless	12302429	\$ 701	\$ 300	\$ 401	175	\$ 70,091
	1st H.P.	AMS 5504/410 Stainless	12286257	\$ 604	\$ 300	\$ 304	175	\$ 53,155
	2nd H.P.	AMS 5504/410 Stainless	12286261	\$ 1,188	\$ 300	\$ 888	175	\$ 155,377
	3rd H.P.	AMS 5504/410 Stainless	12286266	\$ 575	\$ 300	\$ 275	175	\$ 48,038
	4th H.P.	AMS 5504/410 Stainless	12286568	\$ 1,893	\$ 300	\$ 1,593	175	\$ 278,782
5	Fourth (4th) Stage Seal Runner	AMS 5662/Inconel 718	12286490	\$ 319	\$ 200	\$ 119	600	\$ 71,268
				\$ 28,395	\$ 9,150	\$ 19,245	3,235	\$5,563,617

= Cost saving case studies provided in this presentation.

LENS PROCESS OVERVIEW

■ Laser Beam & Powder Delivery



4 Nozzle Powder Delivery

X-Y Gantry Positioning Stage

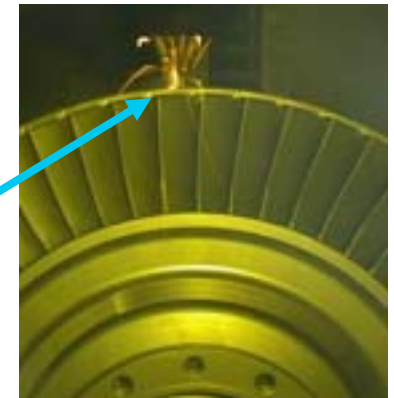
Powder is melted with cw Nd:YAG Laser

Layer by layer part repair or part fabrication



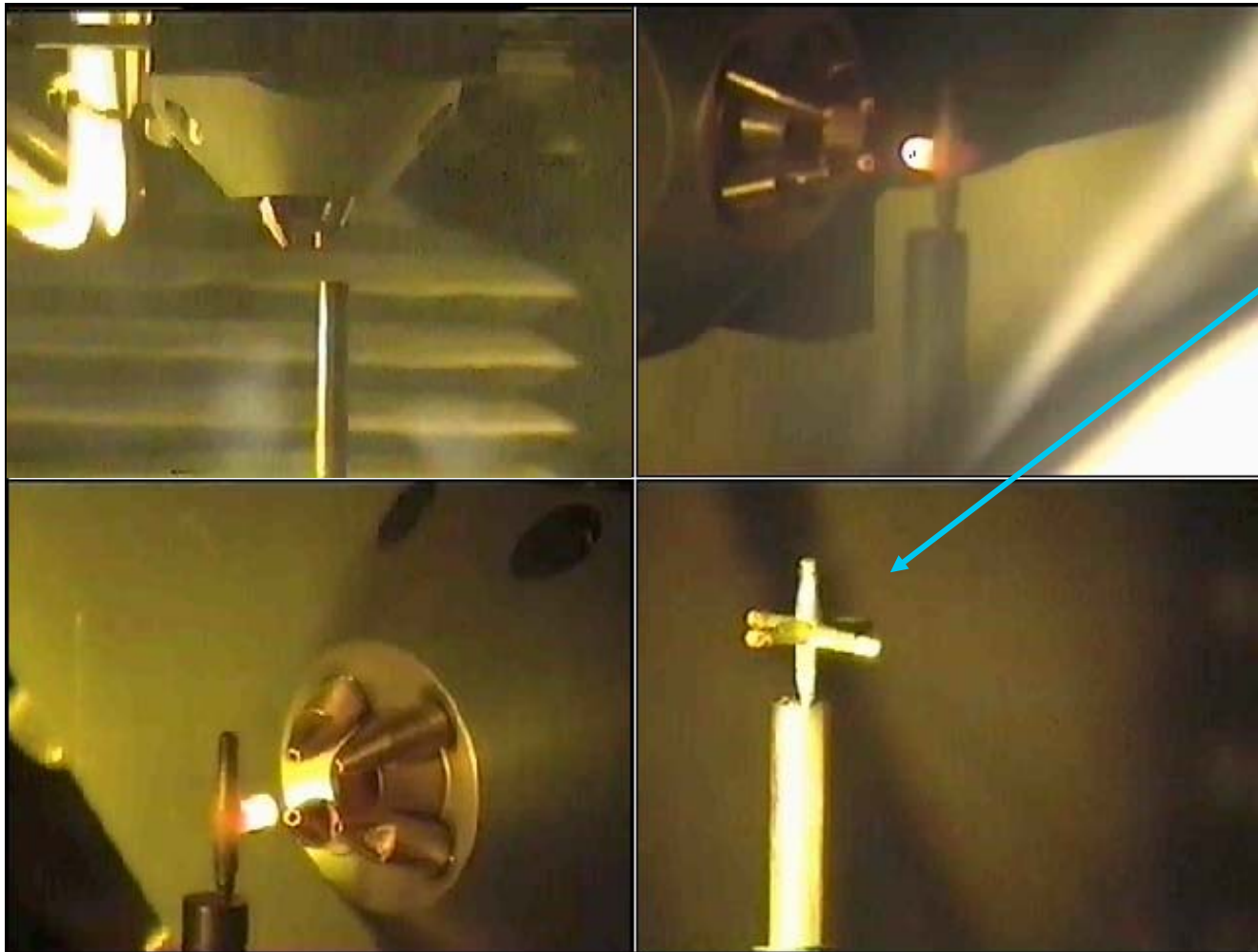
■ Tool Path Generation

- Teach & Learn repair tool path process
- Rotate Stage & radial clad software used for radial repairs
- CAD STL file is used for part fabrication



LENS PROCESS VIDEO

Freeform 5 Axes Laser Wrist Fabrication



6 Point Jack

Proof of Concept Part
for adding LENS to
TACOM's
Mobile Parts Hospital
(MPH) Program

LENS BENEFITS FOR REPAIR

- Small **H**eat **A**ffected **Z**one (HAZ)

Excellent density & adhesion

Minimal effect on the component

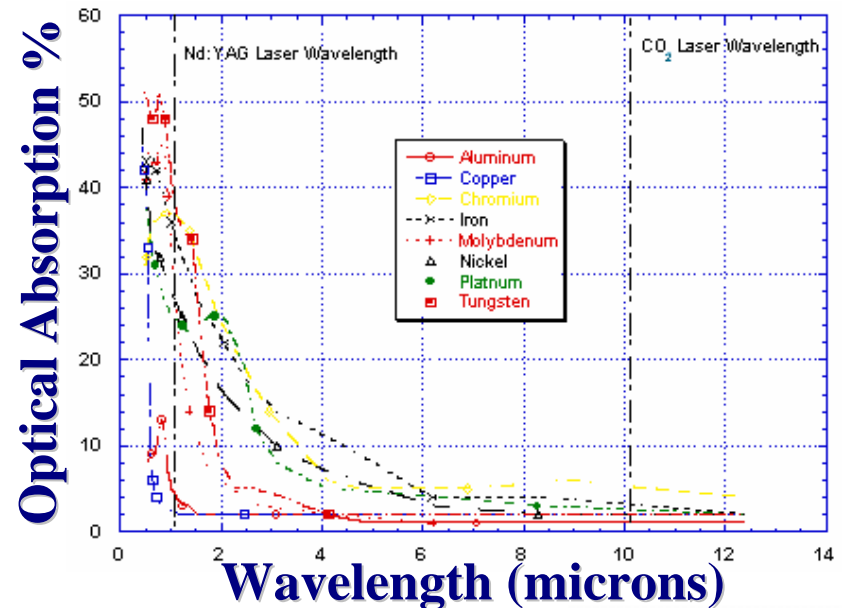


- cw Nd: YAG Laser Material Absorption

Less heat input

Less distortion

Less propensity to crack



LENS BENEFITS FOR REPAIR - *continued*

■ Excellent Material Properties

Titanium Alloy (Ti-6Al-4V)				
	YS (ksi)	UTS (ksi)	Elongation	RoA
LENS - No Heat Treat	155	170	11	N/A
LENS - With Heat Treat	123	139	15	39
Typical Wrought	128	138	14	36
Handbook Minimum	120	130	10	20

■ Atmosphere Controlled Chamber

- optimal and repeatable process environment

■ Near Net Shape Additive Process

- less material waste and post process removal

- significantly better buy-to-fly material waste ratio

■ Computer Controlled Process

- less chance for errors - unattended operation

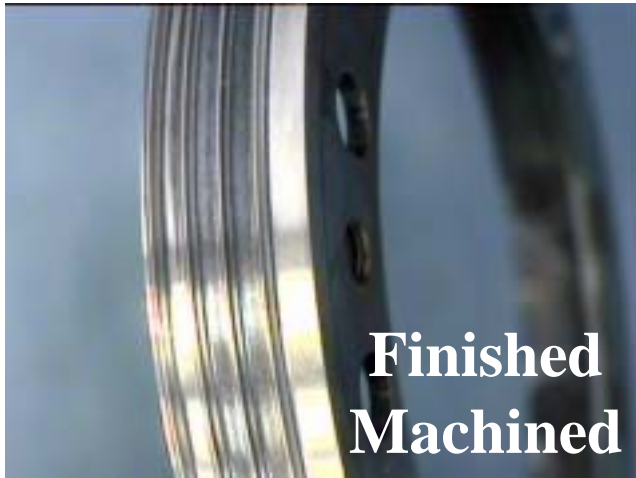


Anniston Army Depot (ANAD) Project Goals

- Reclaim AGT-1500 engine components
- Validate Estimated LENS Phase I Cost Savings
- Provide a more reliable control of production (i.e. availability of parts when needed).
 - ANAD identified a variety of parts that were either high dollar items or items that were not readily available within the supply system.



Fourth (4th) Stage Seal Runner - PN 12286490



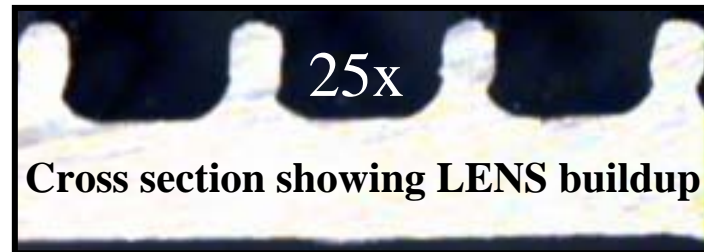
Air Seals Repaired
by LENS

Repair Time: 16 minutes



LENS Procedure:

1. No pre-machining required.
2. LENS buildup utilizing Inconel 718
3. Vacuum heat-treat (Aging).
4. Final machine.
5. Non-Destructive Testing





Fourth (4th) Stage Seal Runner Cost Savings



\$359 - Cost of new (replacement) 4th Stage Seal Runner part
\$120 - LENS Repair Cost (includes prepare, repair, post process)

\$239 - Cost Savings per part

X 546 - Number of 4th Stage Seal Runner parts per year to repair

=====

\$130,494 - Total Cost Savings per year

The U.S. Army Tank-Automotive & Armaments Command (TACOM) approved LENS as a repair process for 4th Stage Seal Runner.



Labyrinth Seal (Balance Restoration) - PN 12271246

Repair Time: 12 minutes

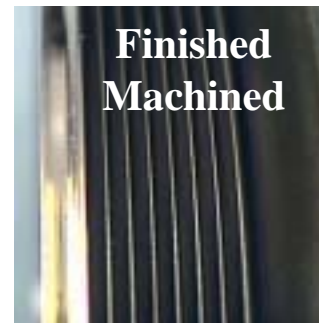
Material Removed
for Balancing



LENS Procedure:

1. Pre-machine balancing areas
2. LENS buildup utilizing Inconel 718
3. Vacuum heat-treat (Aging).
4. Final machine.
5. Non-Destructive Testing

LENS Repair





Labyrinth Seal (Air Seal Restoration) - PN 12271246

Repair Time: 30 minutes

Undersized
Air Seals



Pre-Machine



LENS
Buildup



Finished
Machined

LENS Procedure:

1. Pre-machine down undersized air seals.
2. LENS buildup utilizing Inconel 718
3. Vacuum heat-treat (Aging).
4. Final machine.
5. Non-Destructive Testing





Labyrinth Seal Cost Savings



\$462	- Cost of new (replacement) Labyrinth Seal part
\$250	- LENS Repair Cost (includes prepare, repair, post process)

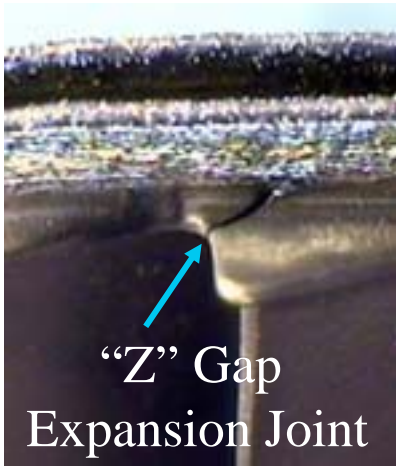
\$212	- Cost Savings per part
X 728	- Number of Labyrinth Seal parts per year
=====	
\$154,336	- Total Cost Savings per year

LENS process parameters are being optimized to increase deposition speed which will significantly improve above noted cost savings.

The U.S. Army Tank-Automotive & Armaments Command (TACOM) pending LENS as a repair process for Labyrinth Seal.



Third Stage (3rd) Stage Turbine Rotor - PN 12271565



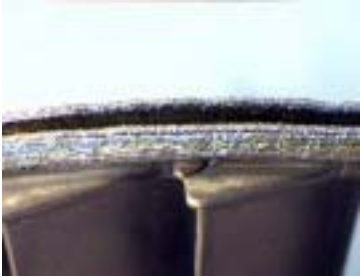
Repair Time: 20 minutes per edge

LENS Procedure:

1. Pre-machine undersized edges
2. LENS buildup utilizing Inconel 625
3. Vacuum heat-treat (Aging).
4. Final machine.
5. EDM new “Z” gap
6. Non-Destructive Testing



Third Stage (3rd) Turbine Rotor Cost Savings



\$7,574	- Cost of new (replacement) 3rd Stage Turbine Rotor part
\$1,000	- LENS Repair Cost (includes prepare, repair, post process)

\$6,574	- Cost Savings per part
x 230	- Number of 3rd Stage Turbine Rotor parts per year
=====	
\$1,512,020	- Total Cost Savings per year

LENS process parameters are being optimized to increase deposition speed which will significantly improve above noted cost savings.

The U.S. Army Tank-Automotive & Armaments Command (TACOM) pending LENS as a repair process for 3rd Stage Turbine Rotor.



Second Stage (2nd) Rotor Disc Cost Savings



\$2,048	- Cost of new (replacement) 2th Stage Rotor Disc part
\$400	- LENS Repair Cost (includes prepare, repair, post process)

\$1,648	- Cost Savings per part
X 218	- Number of 2nd Stage Rotor Disc parts per year
=====	
\$359,264	- Total Cost Savings per year

LENS process parameters are being optimized to increase deposition speed which will significantly improve above noted cost savings.

The U.S. Army Tank-Automotive & Armaments Command (TACOM) pending LENS as a repair process for 2nd Stage Rotor Disc.



PROPOSED FUTURE LENS PART CANDIDATES

- Fourth (4th) Stage Turbine Rotor – Estimated Savings per year \$ 802k.
- Second (2nd) Stage Nozzle – Estimated Savings per year \$ 2.3 million.
- Compressor Stators (HP and LP) – Estimated savings per year \$ 973k.
 - 1st Low Pressure & 1st High Pressure
 - 2nd Low Pressure & 2nd High Pressure
 - 3rd Low Pressure & 3rd High Pressure
 - 4th Low Pressure & 4th High Pressure
 - 5th Low Pressure
- Second (2nd) Stage Compressor Spacer – Estimated Savings per year \$ 80k.
- Compressor Blades (HP and LP) – No calculations on annual savings.
- All Air Seal Components – No calculations on annual savings.

TOTAL ESTIMATED ANNUAL COST SAVINGS FOR LENS REPAIRS

\$ 6,311,114



LENS PHASE I SUCCESS

**TOTAL ESTIMATED ANNUAL COST SAVINGS
AT END OF LENS PHASE I PROJECT**

\$ 6,311,114

14.5% increase over initial Phase I cost savings estimate!!

- DoD's MPPR investment in LENS technology has proven to be a valuable repair process providing faster, better and cost-effective solutions to help ensure readiness and sustainability of weapon systems for our Peacekeepers and Warfighters.
- Input from LENS Phase I partners resulted in design of model LENS-R, Optomec's repair production system.

LENS PHASE II Potential Projects

- ✦ LENS process closed loop control development to insure consistent high quality parts and repairs.
- ✦ CNC Front End Software Development
- ✦ LENS Laser Wrist 5 axes software development for fabricating and repairing complex shapes.
- ✦ “Part to Art to Part” Tool Path Generation
- ✦ Materials Characterization and Process Parameter database development
- ✦ Investigate applications for legacy part replacement
- ✦ Configure LENS system for portable applications
(ie: TACOM Mobile Parts Hospital Trailer/ISO Container / on ship-sub)
- ✦ Application specific nozzle design line of sight fabrication
(ie: fabricate blade on existing blisk)

**ALL LASER FREEFORM FABRICATION & REPAIR APPLICATIONS
WILL BE CONSIDERED**

LENS PHASE I ACKNOWLEDGEMENTS

- Larry Knighton - **Vision for LENS Phase I**
ANAD Division Chief for Industrial Technology Integration & Development
- Walter Atchley - **Investment in LENS Phase I**
DoD MPPR Systems Analyst
- Chuck Gunnels - **LENS Phase I Validation**
ANAD Materials Engineer - Weapons Systems & Lab Division
- Mike Gnam - **Project Management**
NCMS CTMA LENS Phase I Project Manager

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