Outline

- **EWI**
  - Joining and allied technologies

- **Welding Titanium Alloys**
  - Novel low power arc welding
  - High power Laser and Hybrid Laser Arc Welding (HLAW)

- **Additive Manufacturing (AM)**
  - Laser and EB powder bed, EBFF, and Arc Welding

- **Additive Manufacturing Consortium (AMC)**
  - Need for collaboration, especially for design allowables data
  - Response and formation of AMC with 22 partners and members

- **Summary**
EWI - Advanced Manufacturing Technologies

- Additive manufacturing
- Advanced arc welding
- Automation, sensors, controls
- Brazing and soldering
- Dissimilar materials joining
- Friction welding and processing
- Hot forming
- Laser processing
- Nondestructive examination
- Numerical modeling and simulation
- Plastic and composite fabrication
- Resistance welding
- Ultrasonic joining
- Ultrasonic machining
- Weldability testing, mechanical testing, and metallurgical analysis
Precision GMAW

Benefits:
- Reduced heat-input, residual stress, distortion
- Precise deposit shape control
- Filler metal coaxial with the torch
  - Less complex mechanism
  - Easier to automate
- Cost savings (compared to dabber GTAW or laser)
  - Lower capital equipment cost
  - Higher productivity

Need:
- Assess feasibility for high-alloy build-ups
Hybrid Arc (dip and pulse) Metal Transfer

1.5 mm Ti-6Al-4V
Navy application

CMT Fillet Weld, Titanium
Precision-GMAW Build-Up

1.5mm

Stainless steel edge build-up
- 18 ipm Travel speed
- Heat-input < 1 kJ/in
Hybrid Laser-Arc Welding

What is hybrid welding?

- Hybrid Laser-Arc Welding (HLAW)
  - A high-productivity process
  - GMAW + LBW
  - The combination of both welding processes in the same weld pool.
Titanium Alloys

- Deep penetration
- Faster travel speeds
- Smaller melt volume
- Less distortion
- Arc stabilization

6 mm Autogenous and Hybrid

- 3.5 m/min

3 mm

8.13 m/min
12.2 m/min
15.2 m/min

We Manufacture Innovation
For deep-penetration hybrid welding,

- 1mm of penetration for each 1kW of laser power
- With our 15-kW fiber laser at EWI, we have welded up to 16 mm in a single pass
Additive Manufacturing – Progressive Layers

- Build in layers from 3D CAD data, HIP, Stress relieve/PWHT, Machine as/if necessary
Additive Manufacturing
Creating a New Industry

- The Promise - Ultimately from machine directly to part – make things that cannot be made any other way, eliminating many steps in current manufacturing

- The Barriers - Limited data, fragmented development process, most equipment is from overseas (jobs, manufacturing base) and has a small work envelope
AM Processes for Metals

- **EBW freeform fabrication - EB(FFF) (kg/hr)**
- **Laser powder and wire FFF from companies such as POM, Optomec (LENS)**
- **Laser and EB powder bed, from companies such as EOS, and Arcam in confined envelope (g/hr)**
- **Emerging - Arc processes – GTAW-HW, GMAW-P, PTA (wire and powder) based on commercially available equipment for FFF (kg/hr)**
- **Emerging - VHP UAM – very high power ultrasonic AM of strip**
Example Metals AM Processes

- GTAW (Hot Wire)
- Arcam EBM®
- Concept Laser DCM®
- Optomec LENS®
- EOS DMLS®
- Sciaky EBFFF
- MTT SLM®
- Phanix Systems
- MTS Aeromet LAM (No longer in business)

Sciaky EBFFF

MITT SLM®

Phenix Systems
Deposition Rate vs Resolution

- Increased Deposition Rate
- Decreased Resolution

Courtesy Boeing

As deposited
During machining
Finish machined

EWI
We Manufacture Innovation
Example Aerospace Applications

- EB FFF and laser powder (DMLS) parts
- LM Aero calculate 50% cost reduction for EBFFF versus forging for JSF
Example Applications

- **Land vehicles**
  - OEM
  - Repair

- **Power generation and nuclear** - OEM and Repair
Ti-6-4 Vehicle Control arm with GTAW-HW

- First layer and completed deposit
Distortion Control

- End and side views showing low level of distortion
The Additive Manufacturing Consortium (AMC) was founded to provide a U.S. AM forum and is already attracting international interest.

- Consortium of industry, government, and research organizations
- Mission: Advance the manufacturing readiness of metal AM technologies to benefit consortium members
- Goal: Collaboration to generate design allowables data
Advancing Manufacturing Readiness

Manufacturers & Suppliers

Additive Manufacturing Consortium

University & Federal Labs

MRL 8-10
Incremental improvements and implementation
Short time horizon

MRL 3-7
Significant commercial impacts in 2-5 years

MRL <3
High-risk basic research and education
Long time horizon

Time to deployment
AMC

- Rapidly growing network of 22 industry members, government, and university partners – more welcome
- Launched Feb. 2010
- First Members Meeting Dec. 7, 2010 with 20 members/partners
- Recognized AM Aerospace and Defense consortium – *Aviation Week* article Nov. 1/8
- Common voice for coordinated advocacy toward government agency funding of critical needs
Additive Manufacturing Consortium

Goal – Advance the manufacturing readiness of additive manufacturing for the defense industrial base

Government Agencies
- Air Force (Steve Szaruga)
- Army (Stacey Kerwien)
- NASA (Craig Brice)
- NAVAIR (Bill Frazier)
- NIST (Kevin Jurrens)

Industrial Members
- GE
- R-R
- Boeing
- Lockheed Martin
- Northrop Grumman
- General Dynamics
- Morris Technologies
- Applied Optimization
- B6Sigma
- EOS and Sciaky (joining 12/1/11)

Universities/National Labs and Other Partners
- EWI
- The Ohio State University (partner)
- University of Louisville (partner)
- University of Texas (partner)
- North Carolina State University (partner)
- South Dakota School of Mines (partner)
- Lawrence Livermore National Lab (partner)
- TechSolve (partner)
- NCMS (partner)
AMC Technical Priorities

- Property database
- Quality control
- Distortion control
- Equipment development
- Feedstock/input materials
- Design rules
- Standards
- Process modeling/optimization
- AM knowledgebase
AMC - Proposed 1st Year Goals Achieved

- Obtain broad industry and government support – achieved for A&D, reaching out to power, energy, and heavy fabrication community
- Organize “National Test Bed Center” research partners network – in place with extensive equipment and staff resource capabilities
- Identify technology priorities and create development plan – priorities identified for Ti and Ni-based alloys. $60M of government proposals developed
- Conduct state-of-the-art review of metal AM technology - complete
- Establish a database for collecting metal AM property information – will use MMPDS – decided at 6.7.2011 mtg
Summary

- Continued development of arc and hybrid processes for welding titanium alloys for commercial and military uses
- HLAW offers potential for 5/8-in (16 mm) single pass SECB joint or 16mm root using a 15kW laser
- AM is rapidly developing with a range of technologies and Additive Manufacturing Consortium (AMC) is poised for growth into other manufacturing sectors
- AMC offers precompetitive collaboration for development of metals AM using Laser, EB, arc and other processes
Since the early 1980s, EWI has helped manufacturers in the energy, defense, transportation, construction, and consumer goods industries improve their productivity, time to market, and profitability through innovative materials joining and allied technologies. Today, we also operate a variety of centers and consortia to advance U.S. manufacturing through public/private cooperation.