

ABSTRACT

The Reinvention of the Ti-6Al-4V Alloy (From Low Cost Turnings to Component Shape) by Susan M. Abkowitz¹ and Stanley Abkowitz²

The Ti-6Al-4V alloy is the most commonly used titanium alloy of the titanium industry (70% of all alloys) and generates a considerable annual volume of scrap machining turnings (over 30 million pounds globally). These machine turnings currently find application as partial additions to the titanium ingot melting operations or as alloy additives to steel melts. Although useful, the value of these turnings in such applications is limited. The recycle of machined turnings directly to titanium alloy prime billet or to component shape will offer significant cost reduction.

This presentation will review the technical work underway at Dynamet Technology under Marine Corps. sponsorship to produce a cast shape from innovative casting feedstock composed primarily of Ti-6Al-4V alloy machining turnings. These are specially processed to purify the material of contaminants and uniquely consolidated to high density casting electrodes (feedstock). Chemical analysis, microstructure and the impressive mechanical properties achieved with cast material will be discussed along with the potential for significant cost savings.

This innovative process, in addition to producing low cost titanium components represents the green manufacturing of titanium offering significant energy savings along with highly desirable environmental benefits.

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² Stanley Abkowitz is Chief Executive Officer, Dynamet Technology, Inc.



Titanium 2008
ITA Conference & Exhibition
Sept 21-24, Las Vegas, NV

**The Reinvention
of the Ti-6Al-4V Alloy**
Recycled Ti Turnings to Prime Alloy Product

Stanley Abkowitz, Susan M. Abkowitz

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**The Development of Ti-6Al-4V Alloy
Army Watertown Arsenal Laboratory
1952-1955**

June 10, 1954

**First Technical Paper
on Ti-6Al-4V at
Columbia University**

Mimeographed Agenda



The Symposium at Columbia (June 9-10, 1954)

TITANIUM SYMPOSIUM ON DIFFUSION AND MECHANICAL BEHAVIOR
Under Auspices of
METALLURGICAL ADVISORY COMMITTEE ON TITANIUM
Army Ordnance Corps, Watertown Arsenal, Watertown, Mass.

9 and 10 June 1954

at

Columbia University, Men's Faculty Club
117th St. and Morningside Drive, New York, N. Y.

THIRD SESSION - Thursday, 10 June 1954 - 9:00 A.M. to 12:30 P.M.

Chairman: Major R. J. Kotfila, Wright Air Development Center

"Fatigue Characteristics of Titanium and Titanium Alloy Rod at
Minus 40°F., Room Temperature, and 600°F."
A. I. Blank and J. H. Port, Chase Brass and Copper Company

"A Basic Study of the Behavior of Titanium Alloys under Repeated Load"
E. D'Appolonia, Carnegie Institute of Technology

"Effect of Strain Rate on the Creep and Tensile Performance of

FIRST SESSION

Chairman

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Laboratory"

H. E. Martens, California Institute of Technology

12:30 P.M. to 1:30 P.M. - Luncheon at Men's Faculty Club

SECOND SESSION - Wednesday, 9 June 1954 - 1:30 P.M. to 5:00 P.M.

Chairman: L. D. Jaffe, Watertown Arsenal

"The Effect of Hydrogen on Ultrasonic Attenuation in Titanium"
C. F. Ying and R. Truell, Brown University

"Effect of Temperature on Slip and Twinning in Titanium"
F. Rosi, F. Perkins, and L. L. Seigle, Sylvania Electric Products
Incorporated

"Plasticity of Beta Titanium"
P. Albert, New York University

12:30 P.M. to 1:30 P.M. - Luncheon at Men's Faculty Club

FOURTH SESSION - Thursday, 10 June 1954 - 1:30 P.M. to 4:00 P.M.

Chairman: Harold Bernstein, U. S. Naval Gun Factory

"Effect of Grain Size on Fracture of Unalloyed Titanium"
L. Sasa and A. Opinsky, Sylvania Electric Products Incorporated

"Effect of Strain Rate, Temperature, Notches, and Hydrogen Content
on the Mechanical Properties of High-Purity and Commercial-Purity
Titanium and RC-130A Alloy"
O. A. Lenning, C. M. Craighead, and R. I. Jaffe, Battelle
Memorial Institute

"Mechanical Properties of High Strength Tough Titanium Alloys"
S. Abkowitz, Watertown Arsenal

"Mechanical Properties of High Strength Tough Titanium Alloys"
S. Abkowitz, Watertown Arsenal

Glass Lantern Slides



Press Release



Official U.S. Army News Release (May 17, 1954)

Public Information Office
 Watertown Arsenal
 Watertown 72, Massachusetts
 Watertown 4-8540, Ext. 452

FOR RELEASE

MONDAY, 17 MAY - AM PAPERS

NEW ALLOY
Hailed By Army
 Titanium Compound May
 Add Striking Power
 To U. S. Ordnance



Times (m)
 NEW YORK, N. Y.
 Indep.-Dem.
 Circ. 503,999

TITANIUM STUDIES BRING NEW ALLOY

Light Material Developed by
 Army Reported as Tough
 as High-Strength Steel

Special to The New York Times.

WATERTOWN, Mass., May 16
 —Development of a new, light-weight titanium alloy possessing the toughness of high-strength steel was announced today by the Watertown Arsenal Laboratory, an Army center for titanium research.

Col. B. S. Mesick, commanding officer of the arsenal and co-ordinator of the Army titanium research program, said laboratory tests showed the alloy to be 40 per cent lighter in weight than high-strength steel. However, it is highly corrosion-resistant and has properties that compare favorably with those of steel used in making heavy weapons, tanks and armor plate.

While further tests must be made, the alloy is considered a potential substitute for steel in many ordnance components.

The alloy was worked out by Stanley Abkowitz, a member of the arsenal laboratory staff who was serving as a technical supervisor of a contract with the Armour Research Foundation of Chicago. The foundation is one of many agencies engaged in titanium research for the arsenal under Government contract.

The alloy shows tensile strengths up to 192,000 pounds for each square inch, or 42,000 pounds a square inch stronger than any commercial alloy of titanium now being produced.

It also is tougher and more pliable, permitting it to be shaped thus overcoming the brittleness factor that severely limits the use of commercial alloys.

Army Announces
 New Light Alloy
 Equal to Steel

WATERTOWN ARSENAL, WATERTOWN, MASS., May 1954..... Lightweight
 light punch may evolve from a new titanium alloy developed
 Laboratory, Army center for titanium research. Annou
 alloy was made today by Colonel B. S. Mesick, Commanding

Armsen and coordinator of the Army Titanium Research Program
 Laboratory far show that this alloy, ove
 corrosive-resistant, possesses
 with those of high-stren steels now used
 ons, tanks, and armor plate

While further practical value must be mad
 for steel in many ordnance components.
 Special to The Christian Science Monitor
 position of the alloy was formulated by Stanley Abkow
 one of the younger members of the Arsenal Laborat+
 ff.

Super-Tough Alloy Formed

Record (m)
 BOSTON, Mass.
 Independent
 Circ. 391,167

Discover New Alloy for Army Weapons

apture-resisting strengths up
 ds per square
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 time.



*Latest on
Titanium...*

**TITANIUM IN
INDUSTRY**

by STANLEY ABKOWITZ, JOHN
J. BURKE, RALPH H. HILTZ, JR.

For the first time in a single
volume, here is up-to-date infor-
mation on every phase of the
technology of structural titanium
... from production to metallo-
graphic techniques.

224 pages \$5.00

VAN NOSTRAND

250 4th Ave., N. Y. 10001

TITANIUM IN INDUSTRY

By S. ABKOWITZ, J. J. BURKE
and R. H. HILTZ, JR.

(D. Van Nostrand Co., New York,
Publisher)

Here at last is the complete story on titanium; its technology, its capabilities, its potentialities, and its problems, written by three engineers of the Watertown Arsenal Laboratory, which is the center of titanium research and development for the Armed Forces. These men have not only been pioneers in the research and development of titanium but are intensely interested in the future of the metal.

Although the book is a highly scientific treatise on the metal, each subject has been approached in such a manner that it is readily readable by all who will be in contact with the metal from the front office down to the production line.

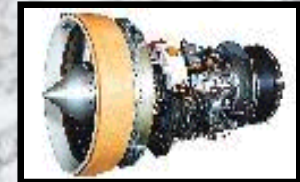
The book provides a brief history of titanium. The main portion of the book is devoted to the following subjects: production of the metal; its physical, chemical and mechanical properties; alloying and heat treatment; casting and powder metallurgy; hot and cold shaping; machining and grinding; surface properties; analytical and metallographic techniques; and selection of alloys and applications. Each chapter is accompanied by an extensive bibliography on the subject. The book is now at press and will be ready early in January. The price is \$5.50.

U2 - Lockheed Skunk Works

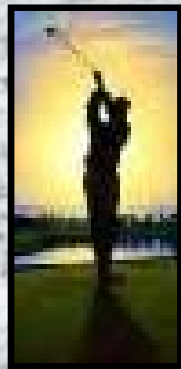


The Lockheed Martin U-2S (Photo Courtesy Lockheed Skunk Works)

Titanium

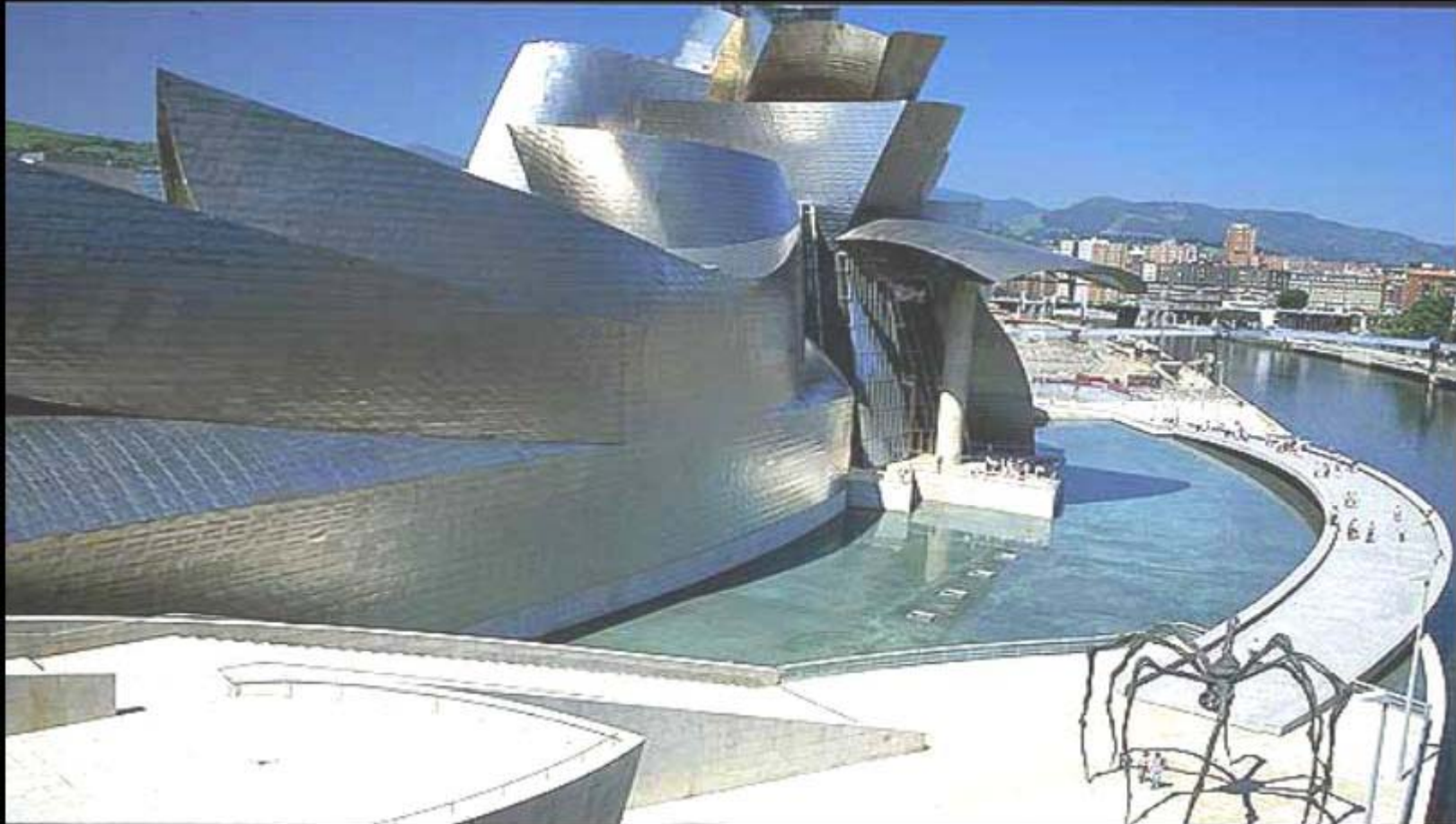


*“...in outer space, in aircraft, on the ground, underground, on the sea, undersea, on the body and within the body.”**

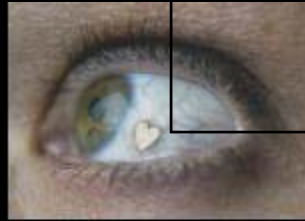


* The Emergence of the Titanium Industry and the Development of the Ti-6Al-4V Alloy,
- Collections & Recollections by Stanley Abkowitz

“On the wall...”



Guggenheim Museum, Bilbao, Italy



“...and off the wall.”



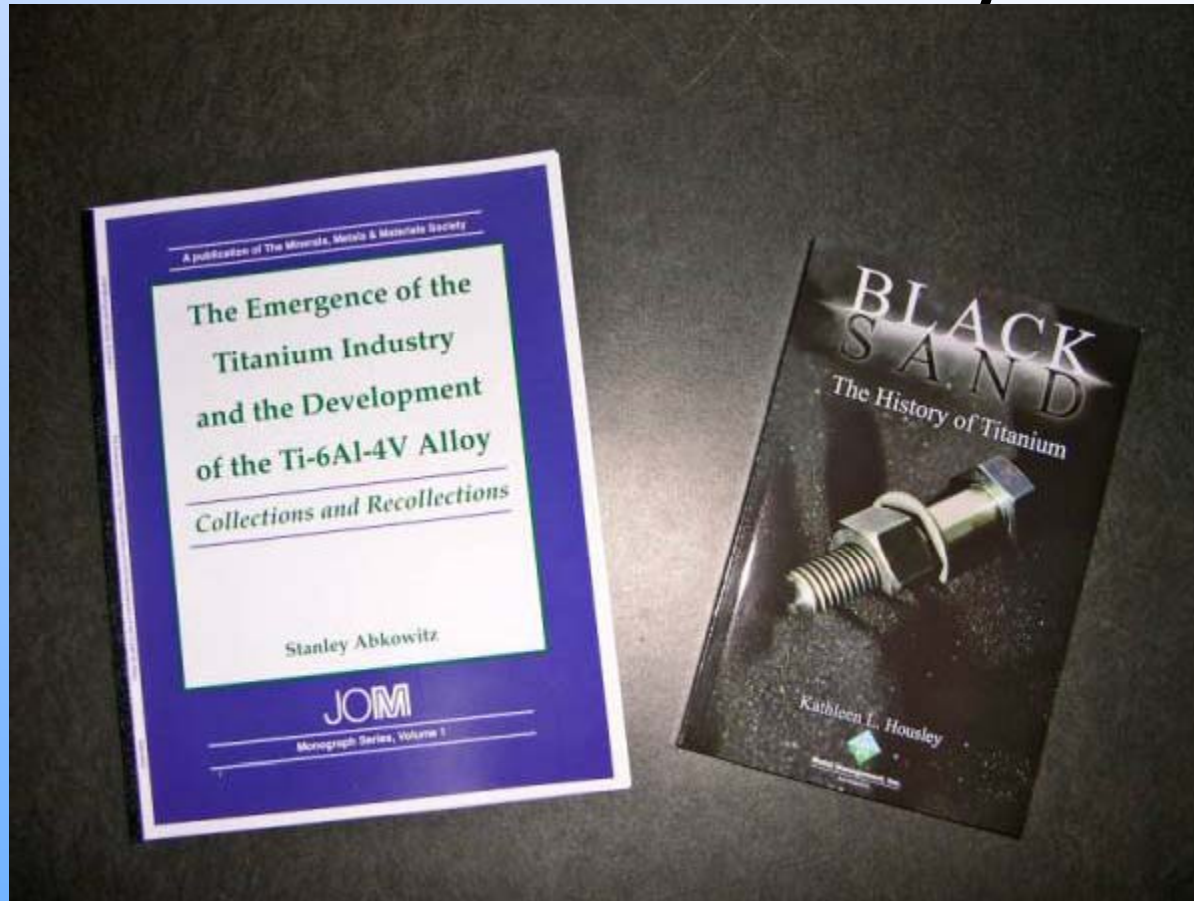
Advantages that led to the widespread use of Ti-6Al-4V

1. From its beginning the alloy was perceived by the manufacturers and the users to be a government-developed, royalty-free alloy.
2. It had the versatility of being both heat treatable and weldable.
3. It could be produced in all mill product shapes such as sheet, plate, tube, bar, pipe, and welding wire (and it offered higher tolerance for hydrogen).
4. It could be readily forged and successfully cast as well as easily machined.

5. With the increasing applications, its mechanical and chemical properties and its fabrication procedures became fully characterized.
6. As it became the basic alloy of choice, recycling of mill scrap was facilitated since the alloy could be segregated, its chemical identity maintained, and significant quantities of a single alloy composition could be economically reclaimed.

The scrap alloy is typically reclaimed by supplementing virgin sponge in melting titanium ingot or used for alloy addition to steel melts.

Titanium History

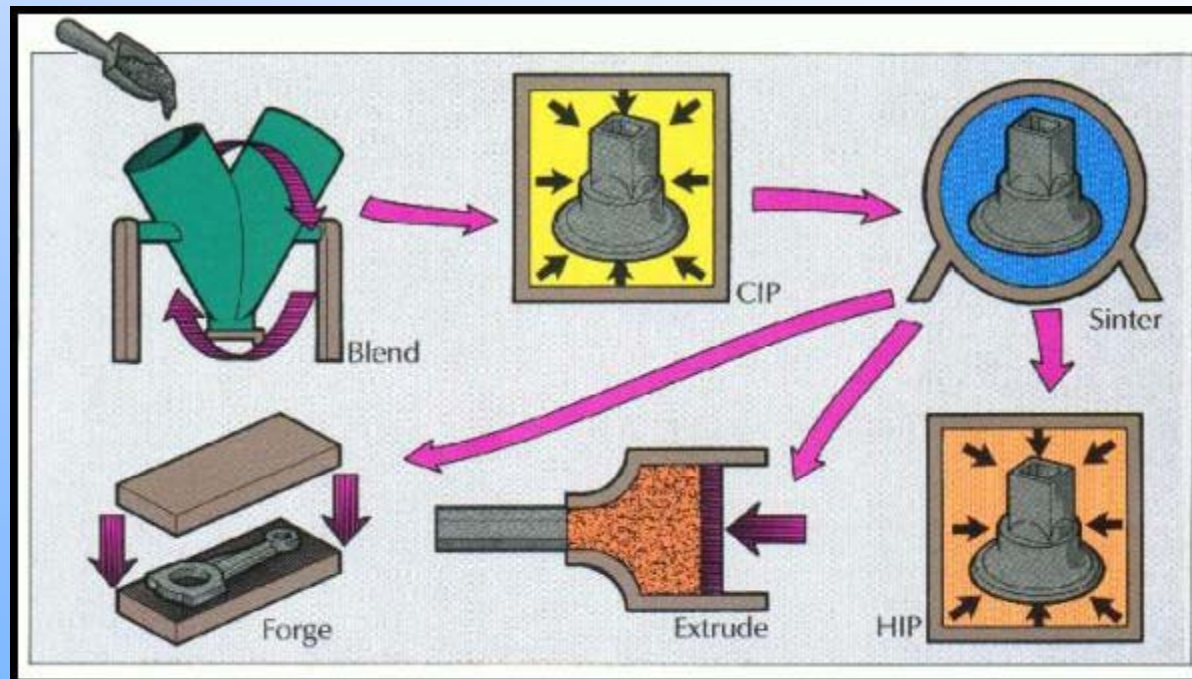


Available from International Titanium Association

Fast Forward To Low Cost Titanium Efforts

Near Net Shape Powder Metal (PM) Manufacturing Technology

The CHIP Process



Dynamet's powder metal CHIP process is used to produce near net shape titanium alloys and MMCs. The PM preforms can also be hot worked to produce forgings and extrusions.

Examples of Cost Saving Production Missile Components



Stinger
Warhead Casing
Ti-6Al-6V-2Sn
CHIP
50,000 parts



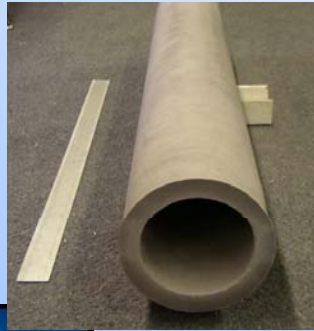
Sidewinder
Dome Housing
Ti-6Al-4V
CIP+Sinter
45,000 parts

Seeker Housing
Ti-6Al-4V
CHIP Process
2,000 parts



50-70% Cost Savings

Current and Emerging Titanium-Based Powder Metal Products



Mill Product Manufacture by PM vs Conventional Ingot Metallurgy

VAR DOUBLE MELT PROCESS

Titanium Sponge



First Melt

Second Melt

Densified, Homogeneous, Alloyed Billet

Forging to Billet



Casting

Extruding

Forging

Raw Material
Yield 66%

DYNAMET PM PROCESS

Titanium Powder Blend



Densified, Homogeneous, Alloyed Billet



Raw Material Yield 98%

Casting

Extruding

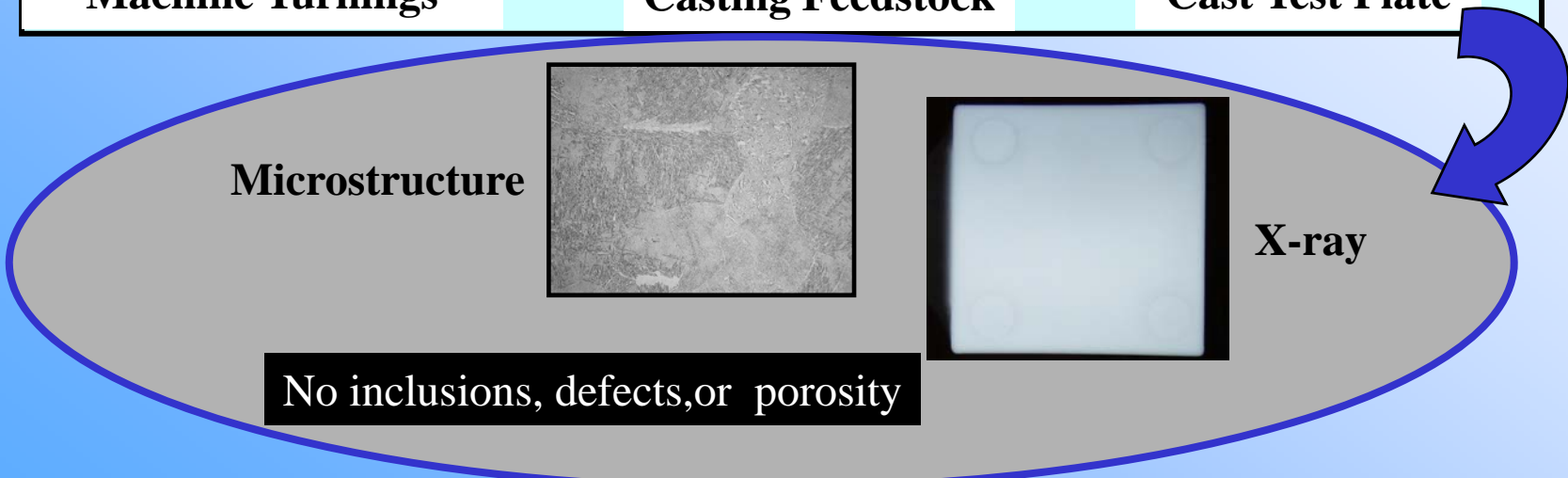
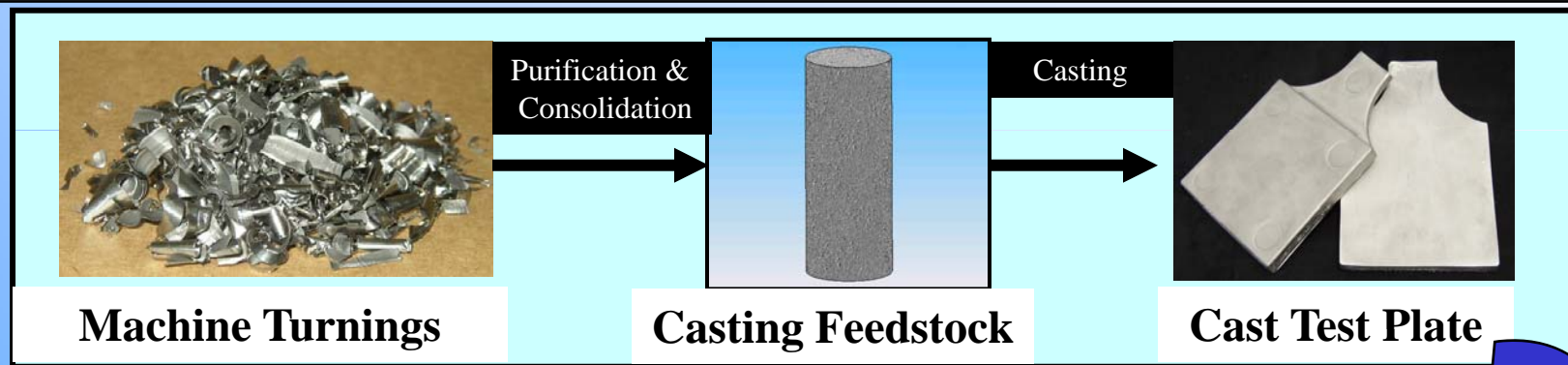
Forging



The Marine Corps Program for Low Cost Ti-6Al-4V Castings for the Expeditionary Fighting Vehicle (EFV)

Low Cost Titanium Feedstock Process

Innovative method for producing low cost Ti-6Al-4V casting feedstock from titanium alloy machine turnings.



LCFP Ti-6Al-4V Casting Results



- ✓ Chemical analyses met applicable specs and were comparable to the baseline Ti-6Al-4V (no tramp elements).

	Al	V	Fe	C	O	N	H	Si
ASTMB367	5.50-6.75	3.5-4.5	0.4 max	0.1 max	0.25 max	0.05 max	0.01 max	0.1 max
Avg LCFP Casting	6.55	4.11	0.21	0.044	0.25	0.014	0.0008	0.049

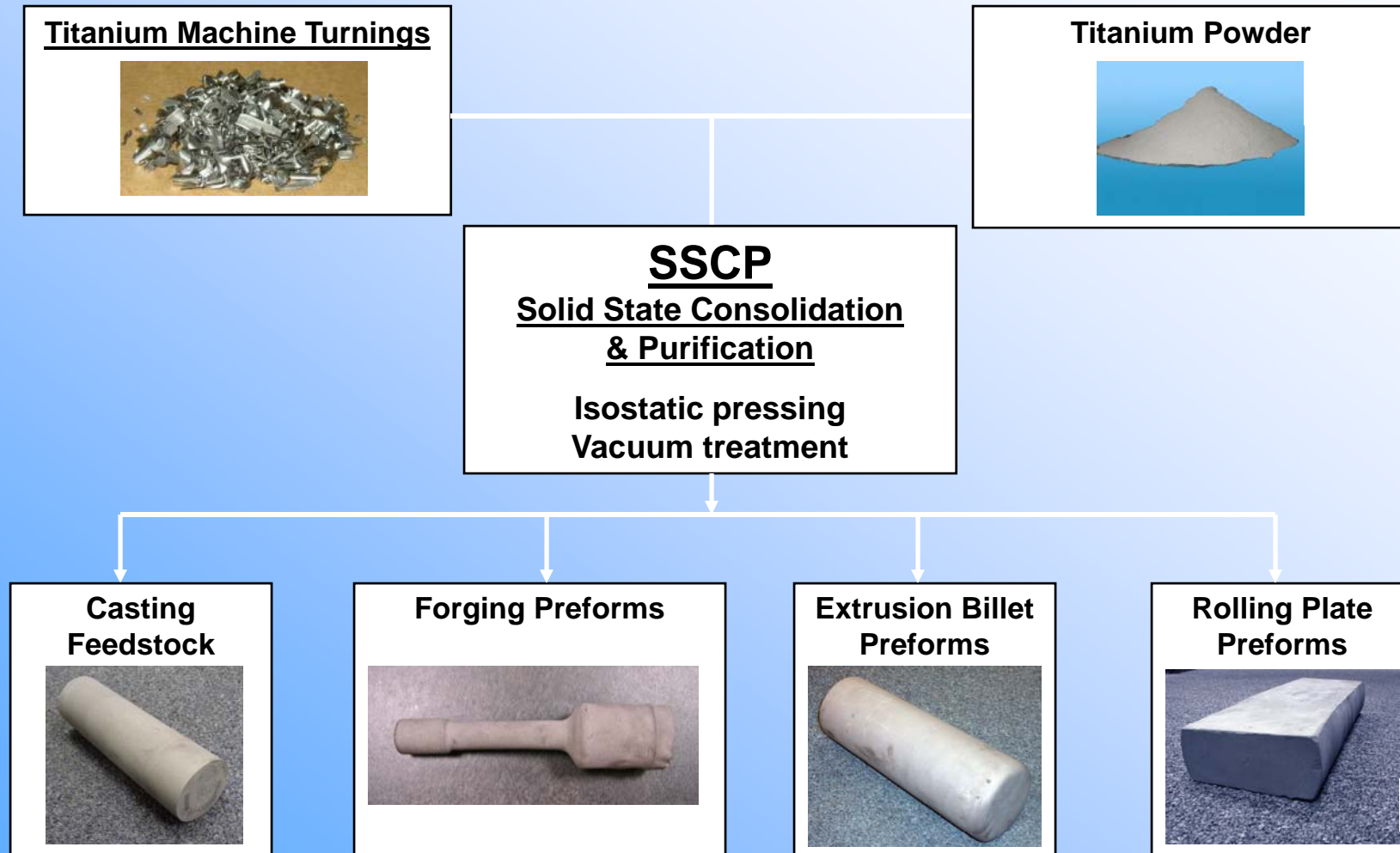
- ✓ Tensile Properties met applicable specs and were comparable to wrought Ti-6Al-4V.

Material	UTS (ksi)	YS (ksi)	EI (%)
Avg LCFP	155.3	137.1	12.1
AMS 4985 & ASTM B367 (castings) Min.	130	120	6.0
AMS 4928 (wrought) Min.	130	120	10.0

- ✓ Projected Cost Savings: 30-60%

**The Advantage of Using Low Cost
Powder *Plus* Scrap Recycle to
Produce Extra Low Cost
Prime Mill Product**

Integrated PM/Recycled Ti-6Al-4V



The Creation of NuLife Titanium LLC