

COMPUTATIONAL MATERIALS DESIGN: Making CyberSteel Fly

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NORTHWESTERN
UNIVERSITY

QUESTEK[®]
INNOVATIONS LLC

First Flight: QuesTek *Ferrium S53*[®] T-38 main landing gear piston December 17, 2010



Material approval:	November 2009
Component approval:	August 2010
Component installation:	November 2010
First flight:	December 2010

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MTL/SRG

A) Cybersteel 2020 (ONR-DARPA D3D; AM)

B) HT Carburizing Steels (DOE-OIT; GM)

C) Cyberalloys/SMA (NASA, ONR, DARPA, MDT, GM, Ford/Boeing)

D) Bulk Metallic Glasses (DARPA-SAM, ONR)

GOVERNMENT

NAWC/AD	A
Lee	
NRL	A
Spanos	Rowenhorst
Fonda	
ARL/WMD	B
Montgomery	Mathaudhu
AFRL	C,D
Woodward	Miracle
Simmons	

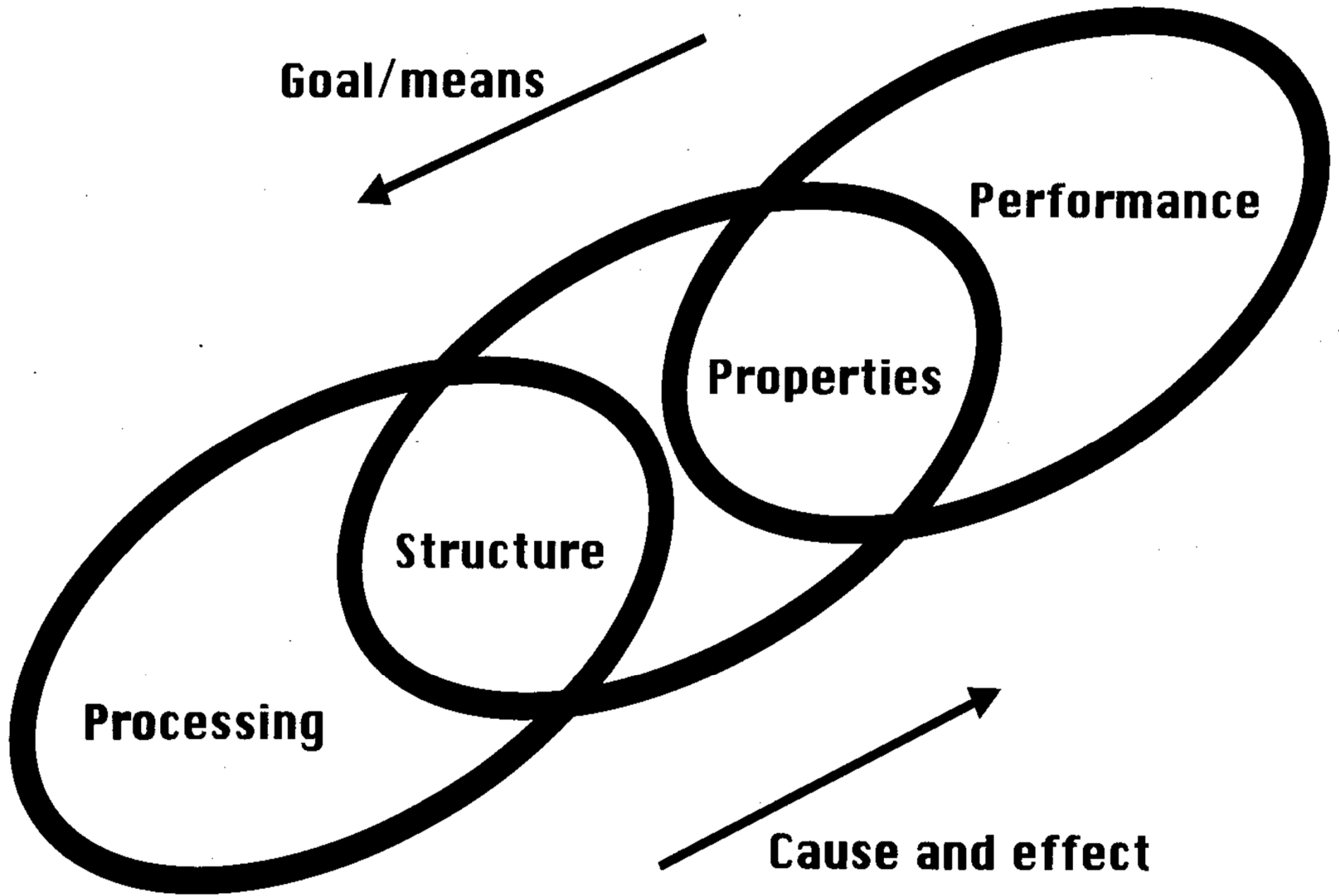
FLORIDA	C
Manuel	
LEHIGH	C
Harlow	
WISCONSIN-MAD	C,D
Perepezko	
IIT	C,D
Nash	

UNIVERSITY

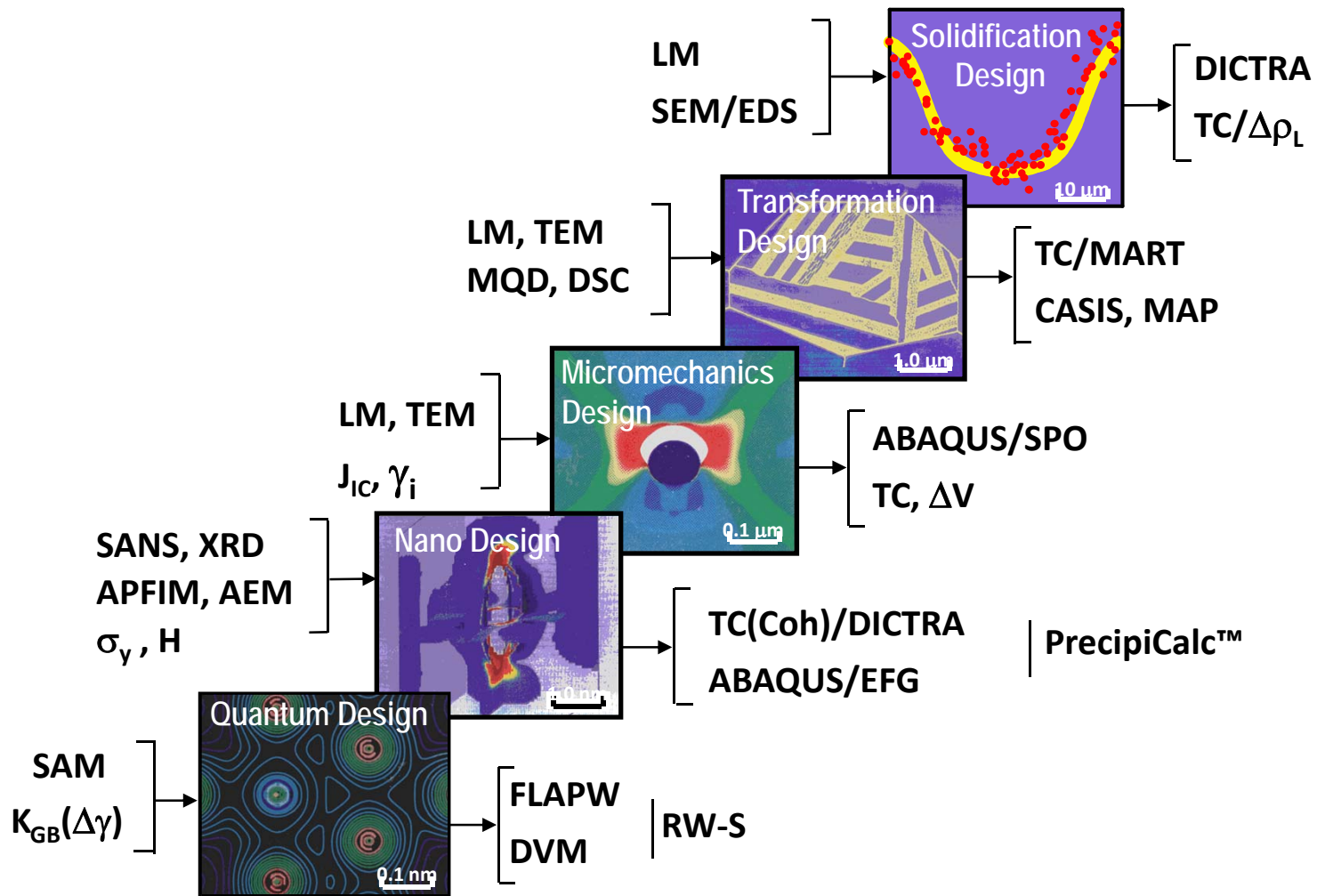
NORTHWESTERN	A,B,C,D
Olson	Freeman
Brinson	Isheim
Chen	Jerome
Espinosa	Liu
Fine	Voorhees
High Resolution Microanalysis	
GIT	A
McDowell	
UCSB	A
Pollock	
CSM	A,C
Eberhart	
OHIO STATE	A,C
Fraser	Mills
Lippold	Babu
MIT	A,D
Parks	
WPI/CHTE	B
Apelian	Backman
PURDUE-CALUMET	B
Abramowitz	
KTH (Stockholm)	C
Agren	

INDUSTRY

QUESTEK	A,B,C,D
Kuehmann	Jou
Misra	Wang
Counts	Kern
Prasanna	Wright
Huang	Jung
Sebastian	
ARCELOR-MITTAL	A
Bhattacharya	Yakubovsky
LATROBE STEEL	A,B
Tomasello	Balliett
CATERPILLAR	A,B
Chen	Johnson
Sherman	
ALLVAC STEEL	A,B
Lippard	
SFTC	A
Bandar	
GM	B, C
Sachdev	Sarosi
FORD	B,C
Li	Sherman
BOEING	C,D
Bowden	Sankaran
PRATT & WHITNEY	B,C,D
Fowler	Schirra
Watson	
MEDTRONIC	C
Adler	
HOWMET	D
Wolter	



Hierarchy of Design Models



CyberSteels to Market

GearMet C61

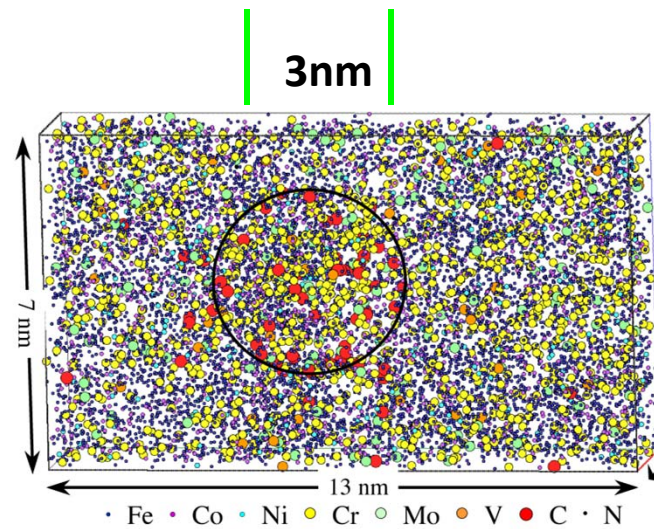
AMS6517

Ferrium S53 Stainless

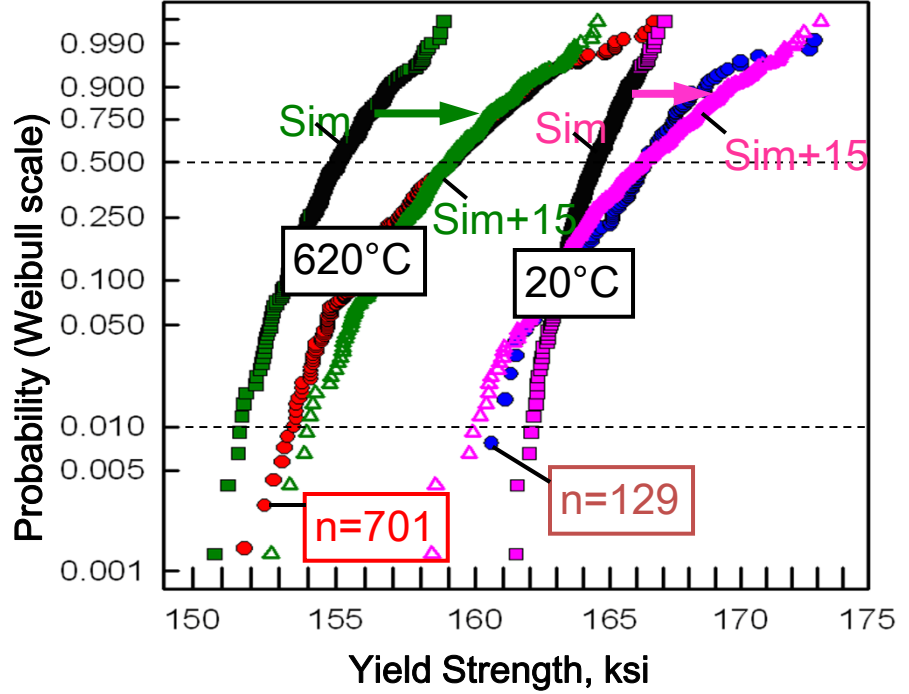
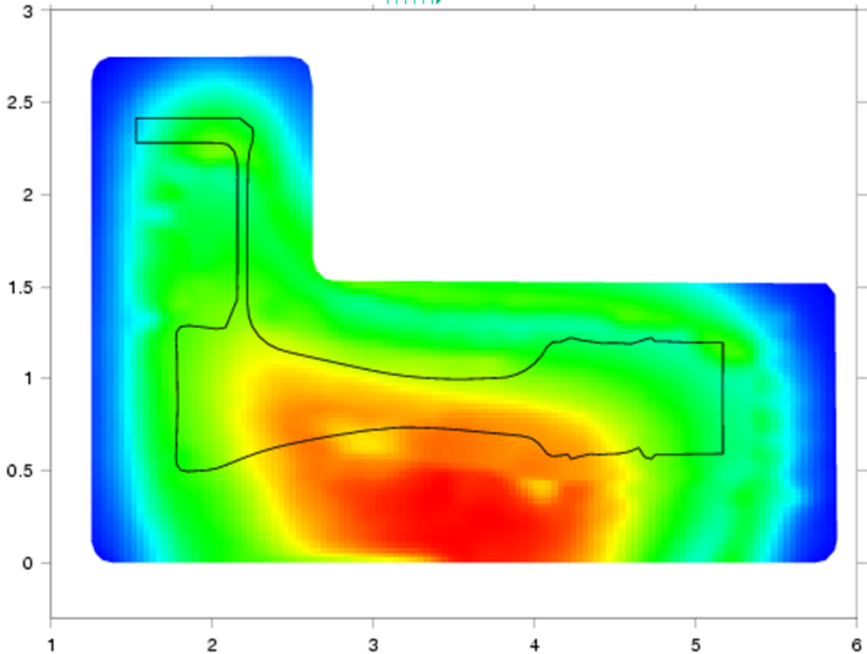
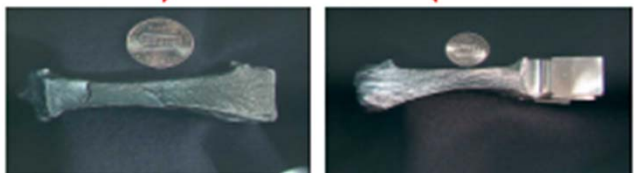
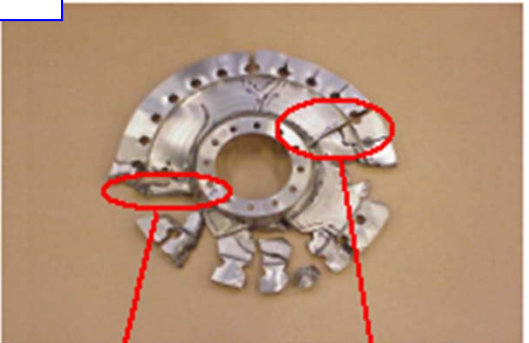
AMS5922



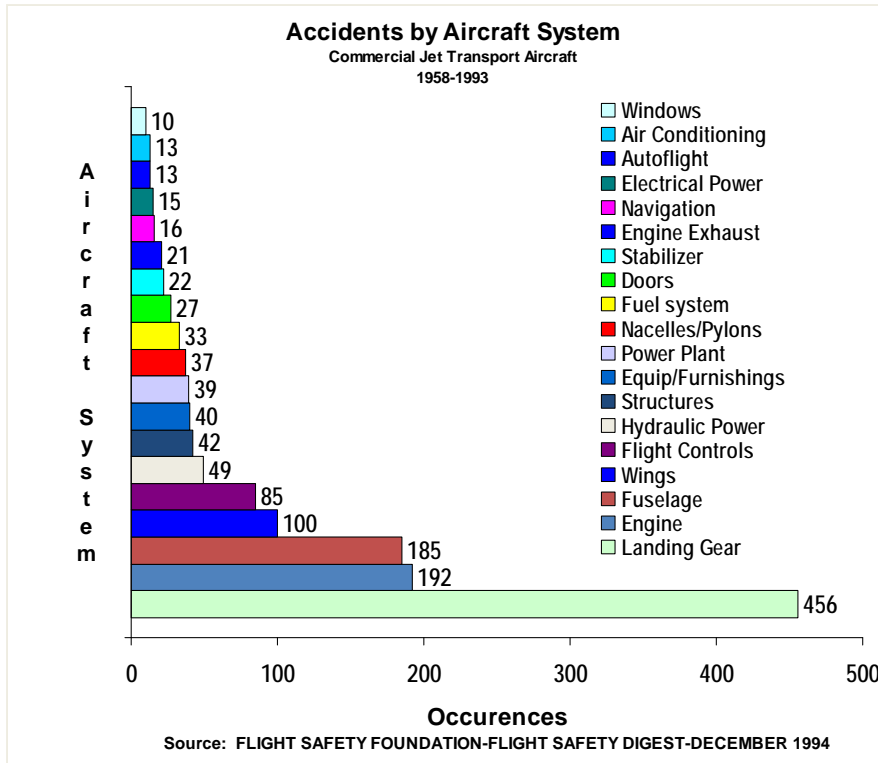
A10



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UHS Stainless Steel for Landing Gear



Issues:

Over \$200M spent in LG per year
80% corrosion related SCC failures
Cad plating used to protect current steel
Known carcinogen (AF 2000 lb/yr)

SCC failure

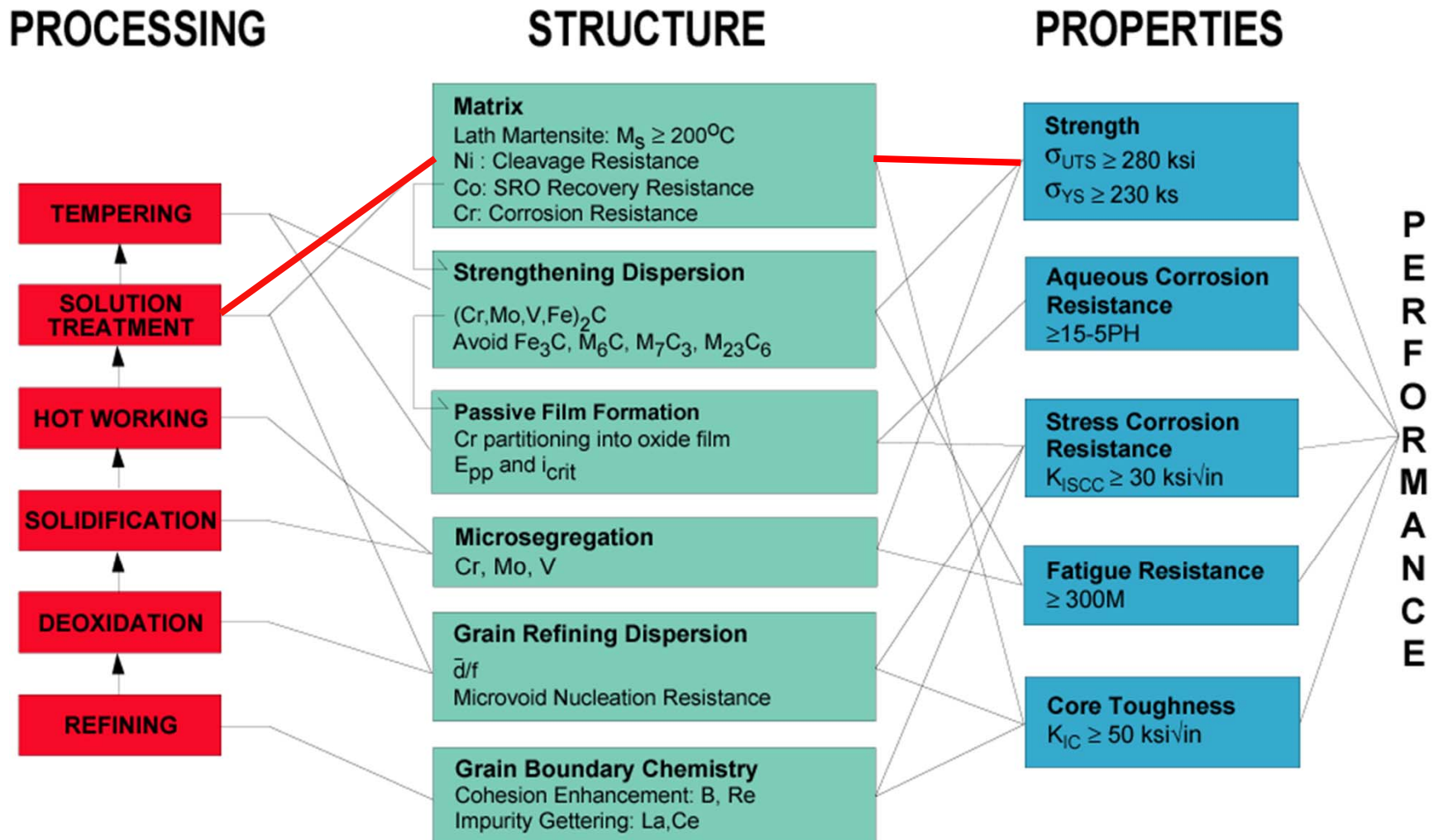


HE failure

Stainless Benefits:

Dramatic reduction in LG cost (60%= \$120M per year)
Significant reduction in SCC failures
Cadmium plating not required
General corrosion mitigated
80% of Steel Condemnsions Avoided

S53 System Flow-Block Diagram



S53 Robust/Sensitivity Analysis with Compositional Variation

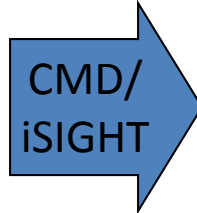
Compositional Variations

(wt%, $\pm 6\sigma$):

C ± 0.01 Cr ± 0.2 Mo ± 0.1

W ± 0.1 Co ± 0.3 Ni ± 0.1

V ± 0.02

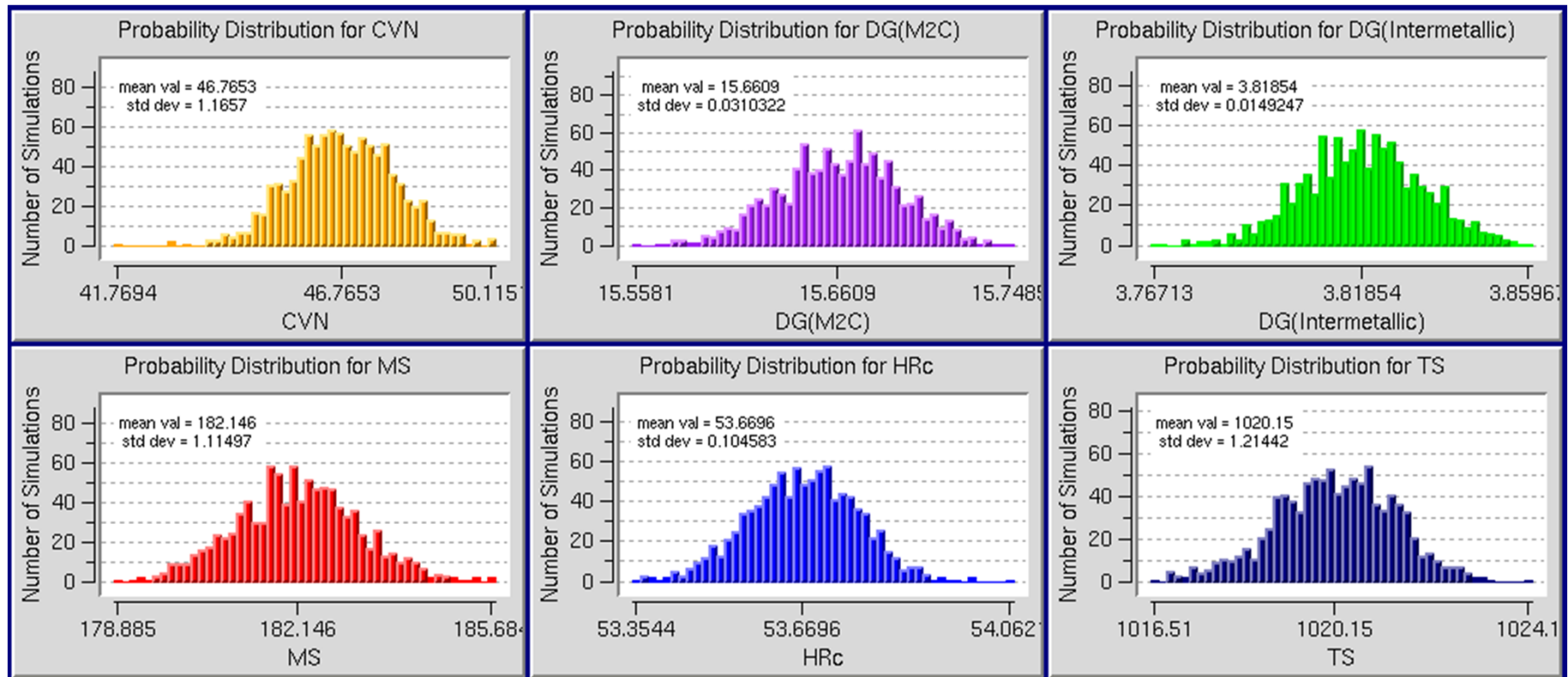


Variations of:

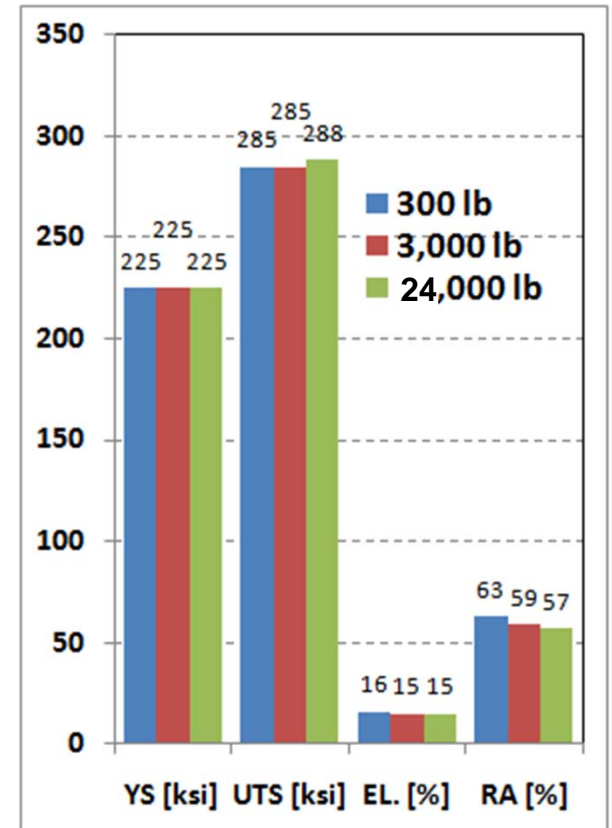
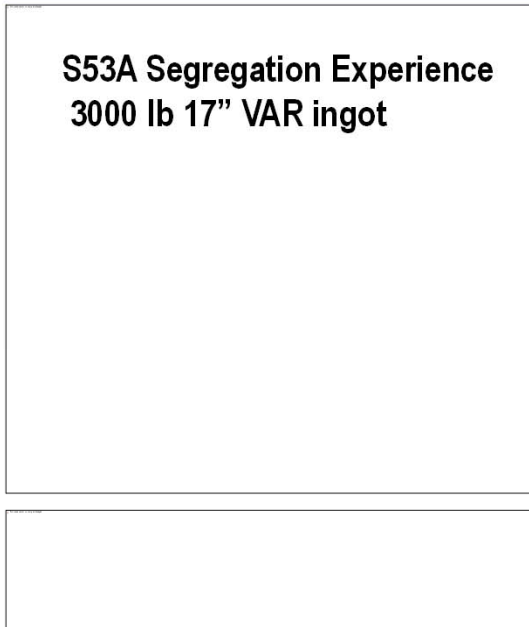
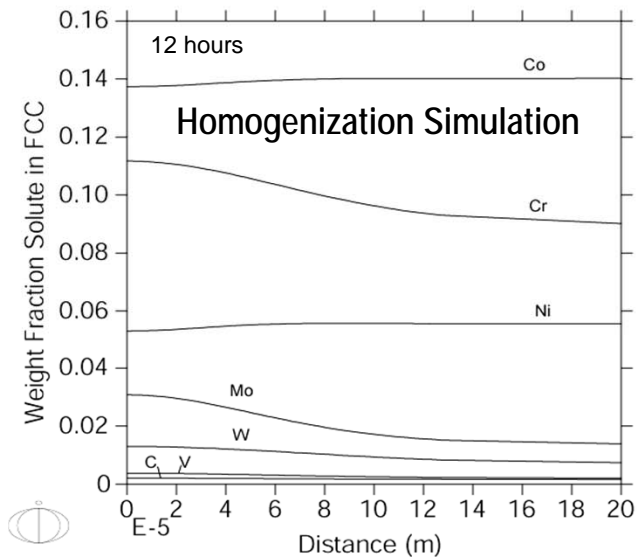
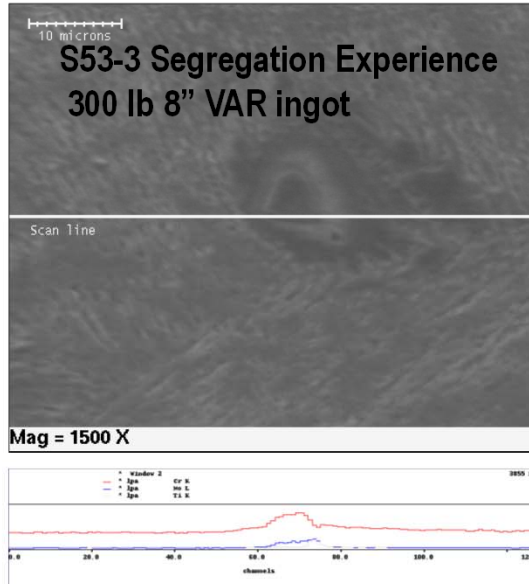
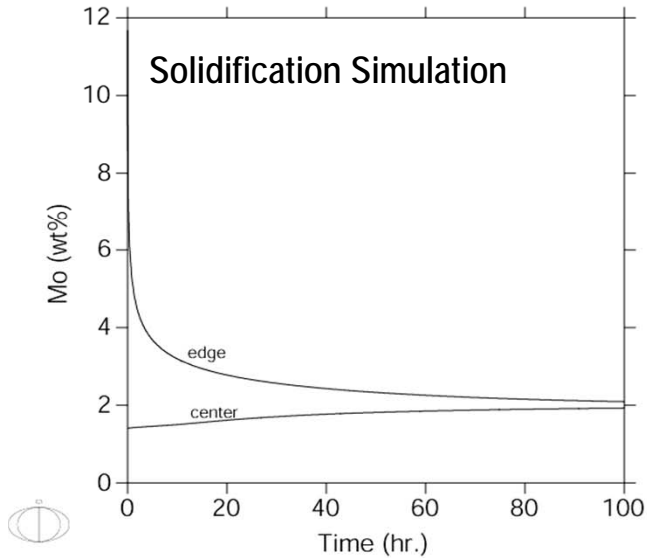
Structure — carbide solvus Ts, martensite Ms, precipitation control ΔG 's

Property — hardness HRc, toughness CVN

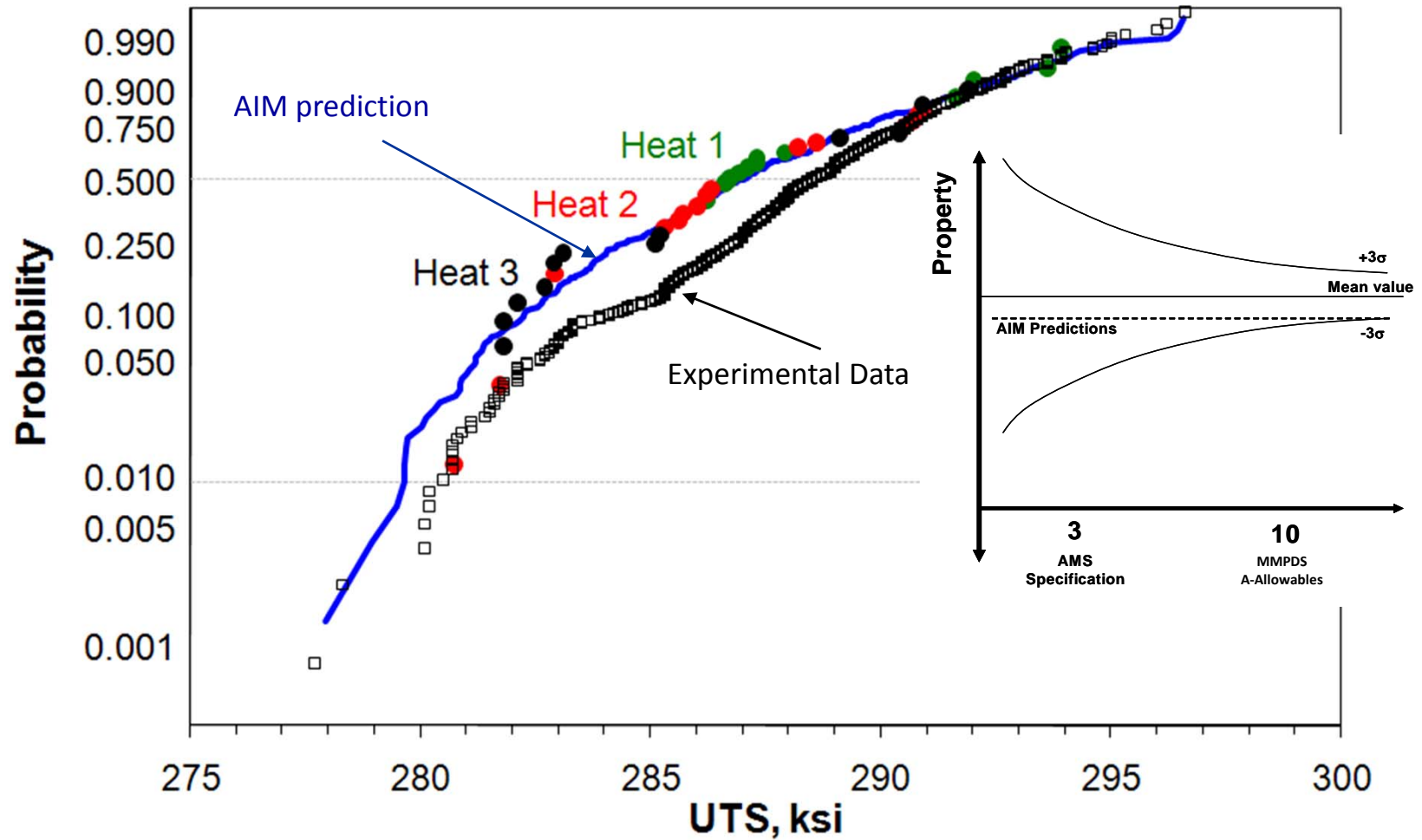
Results of 1000 runs (12 minutes on a Pentium IV 2.2GHz CPU)



Ferrium S53 — Design For Scale

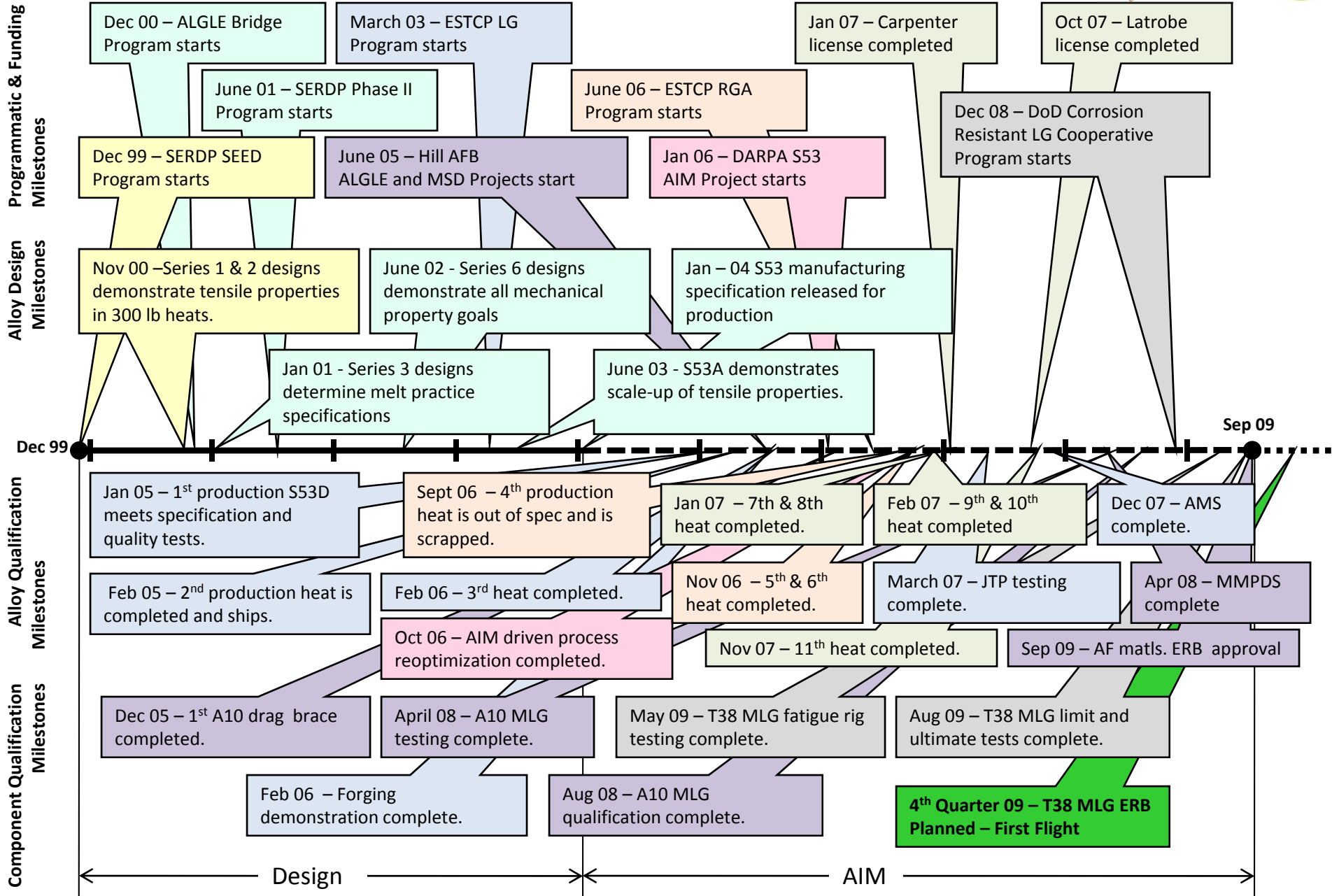


S53 AIM Analysis for UTS





S53 Development Milestones



Technology Transfer

QUESTEK® Navy Alloy Designs

Marine Corps: M67854-05-C-0025



NAVAIR: N68335-05-C-0207 and N68335-07-C-0108



NAVAIR N68335-10-C-0174



OSD N00014-09-M-0400



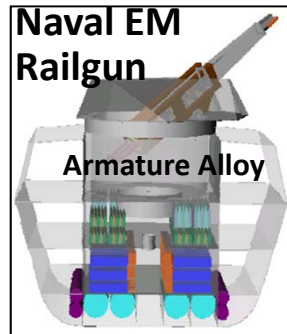
NAVAIR: N68335-07-C-0302 and N68335-08-C-0288



ONR: N00014-07-M-0445 STTR-I



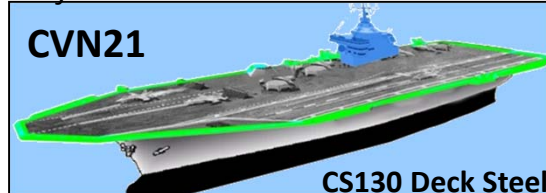
ONR: N00014-09-M-0220



NAVAIR: N68335-07-C-0428



Navy/ONR: N00014-05-C-0241



Navy: N65538-09-M-0088



Marine Corps: M67854-10-C-6502



ONR: N00014-08-M-0309



ONR: N00014-05-M-0250
NAVAIR: N68335-06-C-0339



NAVAIR: N68335-09-C-0215



NAVAIR N68335-10-C-0229



