NEW DEVELOPMENTS IN ALUMINUM FOR AIRCRAFT AND AUTOMOBILES

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Common bond for aircraft and automobiles is need for cost-efficient, lightweight structure.

Aluminum base materials

New Developments in Aluminum for Aircraft and Automobiles

- **Automotive**
  - **Needs**
  - **Developments**
  - **Directions**

- **Aircraft**
  - **Needs**
  - **Developments**
  - **Directions**

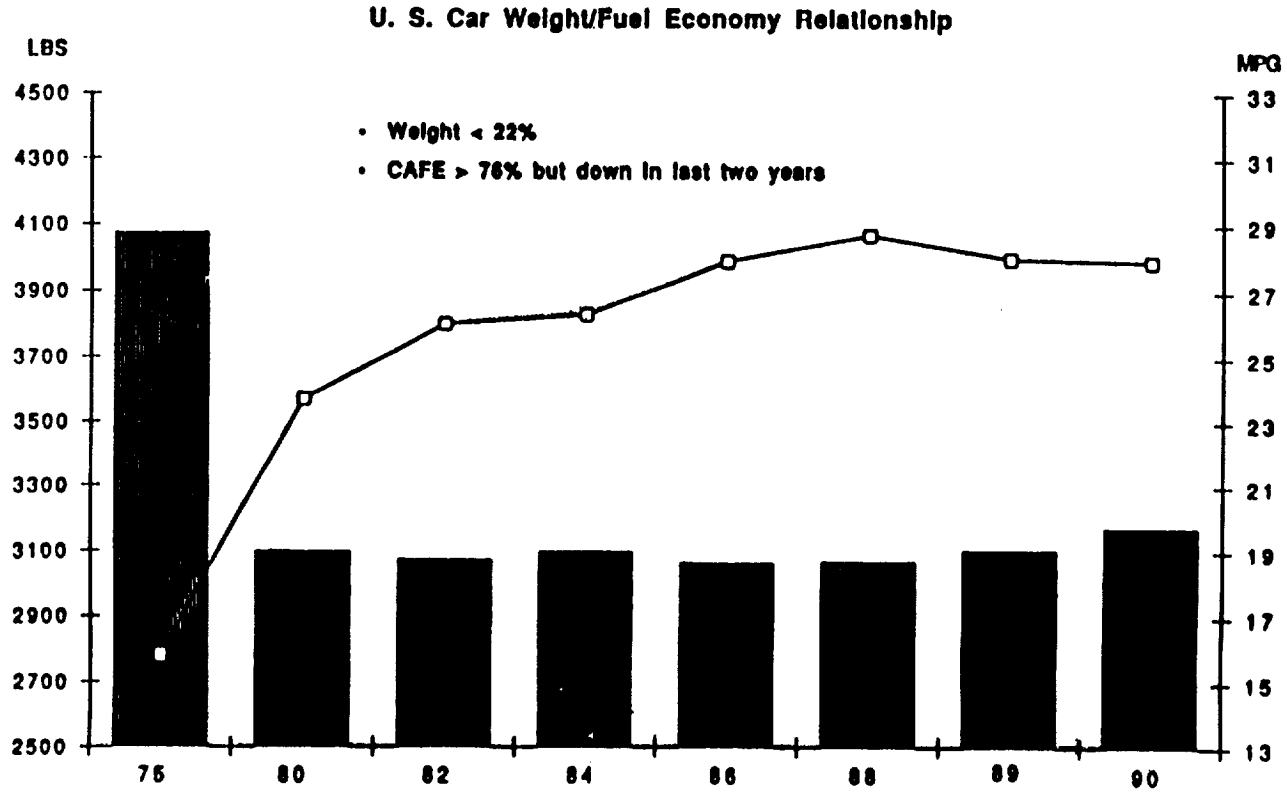
Forces Shaping Future Automotive Materials Needs

- Need for fuel efficiency
- Changing consumer preferences
- Growing environmental awareness
- Globalization of market

BACKGROUND, AUTOMOTIVE

1975 TO 1991 - SOURCES OF REDUCTION IN FUEL CONSUMPTION

TIRES	22.4
WEIGHT	32.2
AERODRAG	34.7
POWER TRAIN	10.7
	100%



Source: U. S. Environmental Protection Agency

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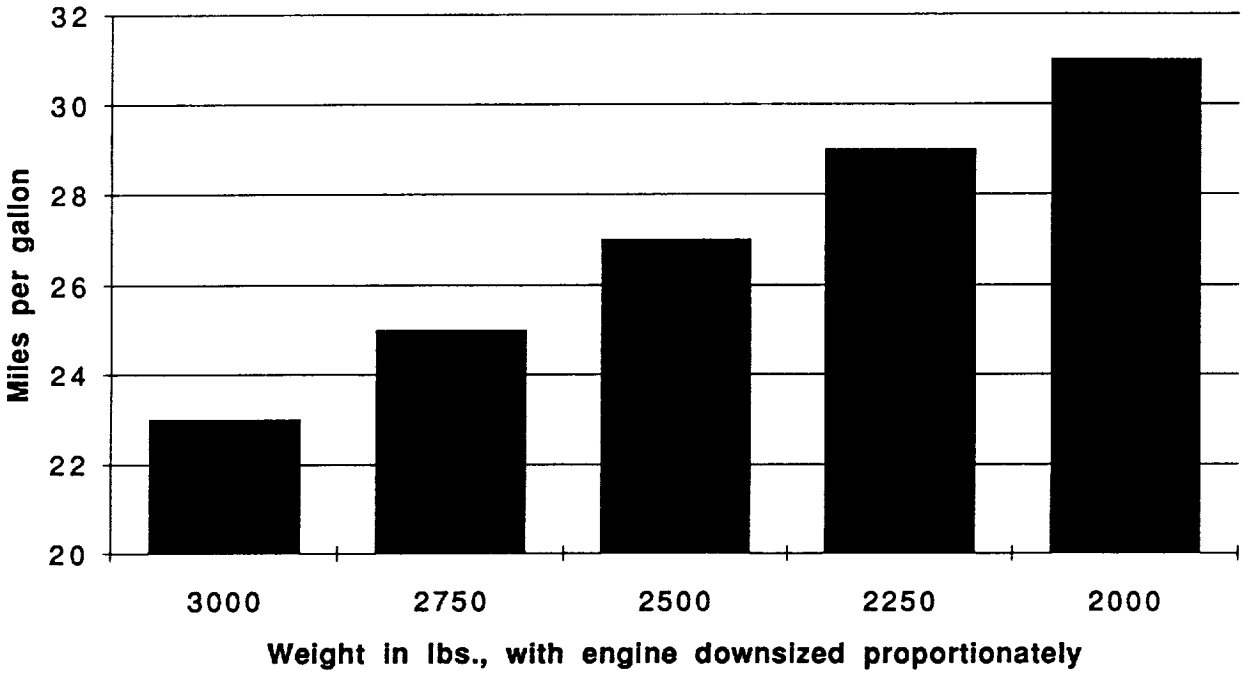
Automotive

Why use aluminum?

- Weight reduction
  - Increased fuel economy
  - Decreased emissions
  - Increased performance
  - Increased cargo capacity
- Longer vehicle life
- Recycling capacity

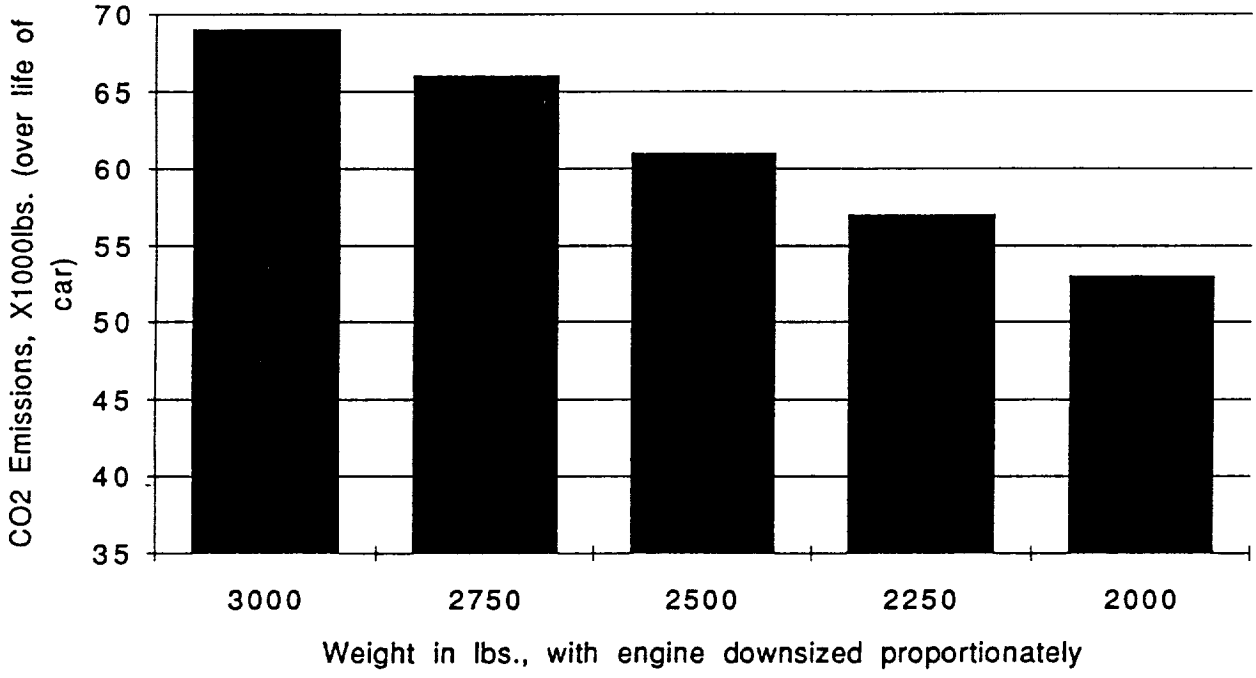
Energy Cycle

LOWER WEIGHT = HIGHER MPG



CAR WEIGHT/EMISSIONS

LESS WEIGHT = LOWER EMISSIONS



Aluminum Strength/Weakness versus Competitive Materials

Al Strength vs Steel

- Lightweight effectiveness
- Corrosion Resistance

Al Strength vs Plastic

- Lightweight effectiveness
- Stiffness
- Recyclable
- Ease of repair

Al Weakness vs Steel

- Stiffness
- Ease of manufacturing
- Cost

Al Weakness vs Plastic

- Design options
- Corrosion resistance
- Dent resistance

Automotive

- **Hang-on components**

Automotive

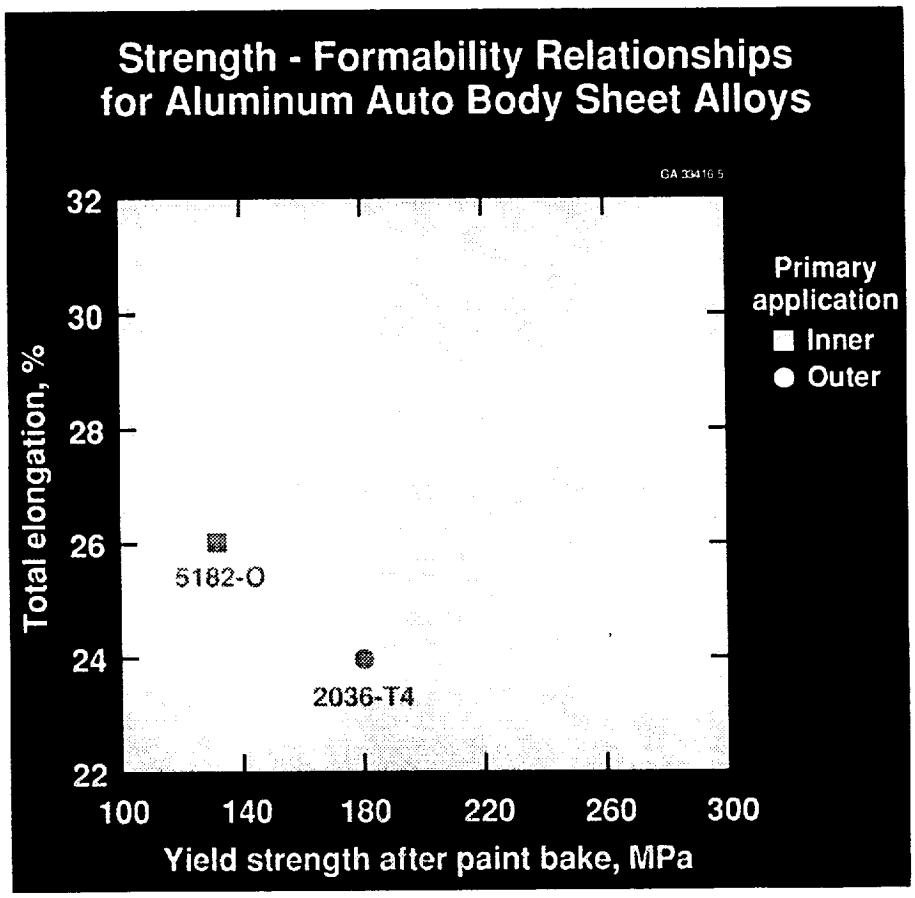
Hang-on components

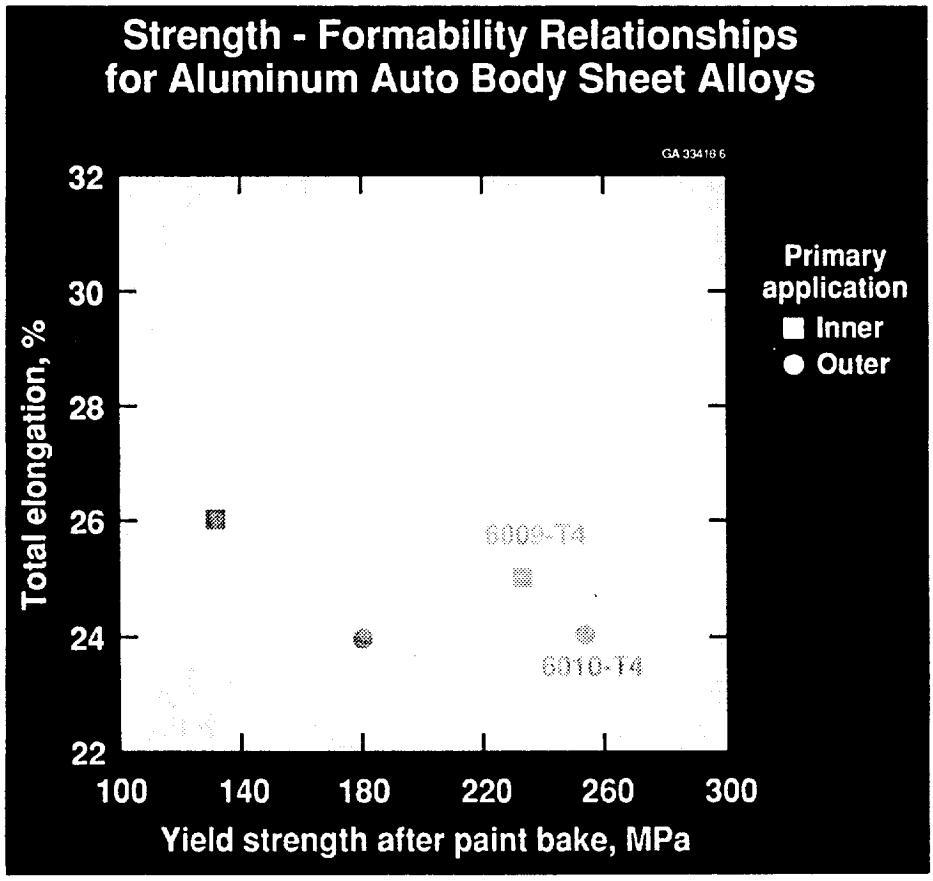
- Outer panels
  - Class A surface
  - Corrosion resistant
  - Y.S.
  - U.S. and Europe: > 207 MPa
  - Japan: 138 MPa < Y.S. < 172 MPa
  - Formable
    - Stretchable
    - Drawable
    - Hemmable
  - Alloys
    - 2XXX
    - 6XXX

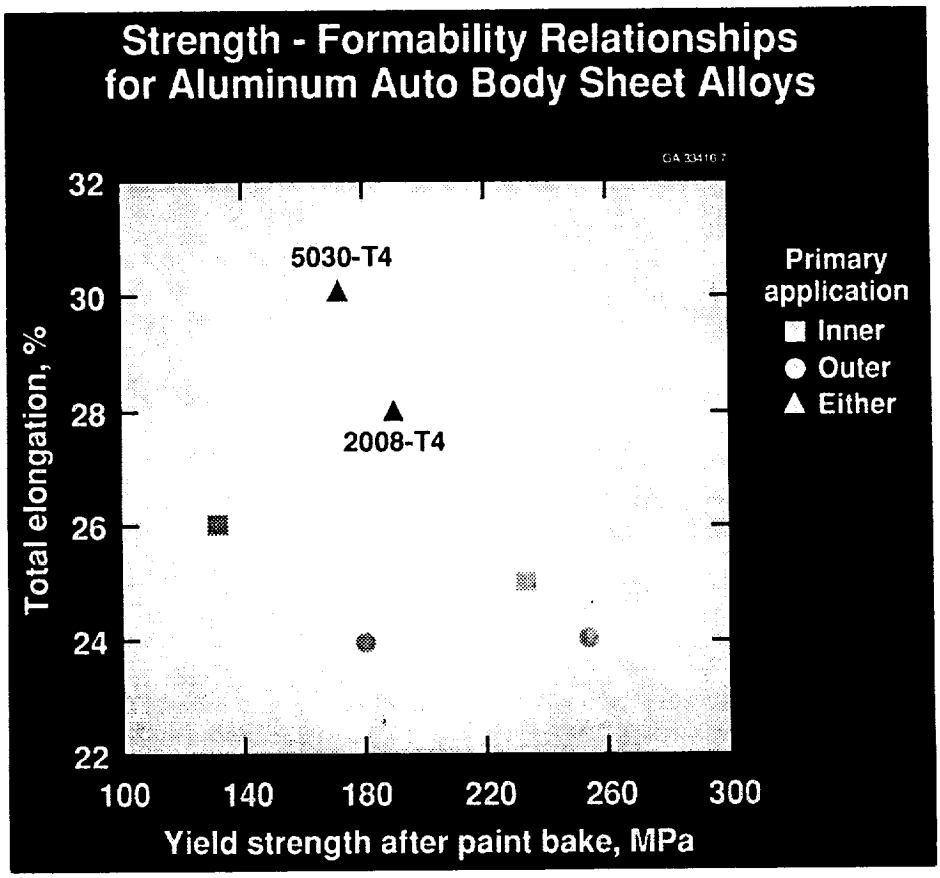
Automotive

- **Hang-on components**

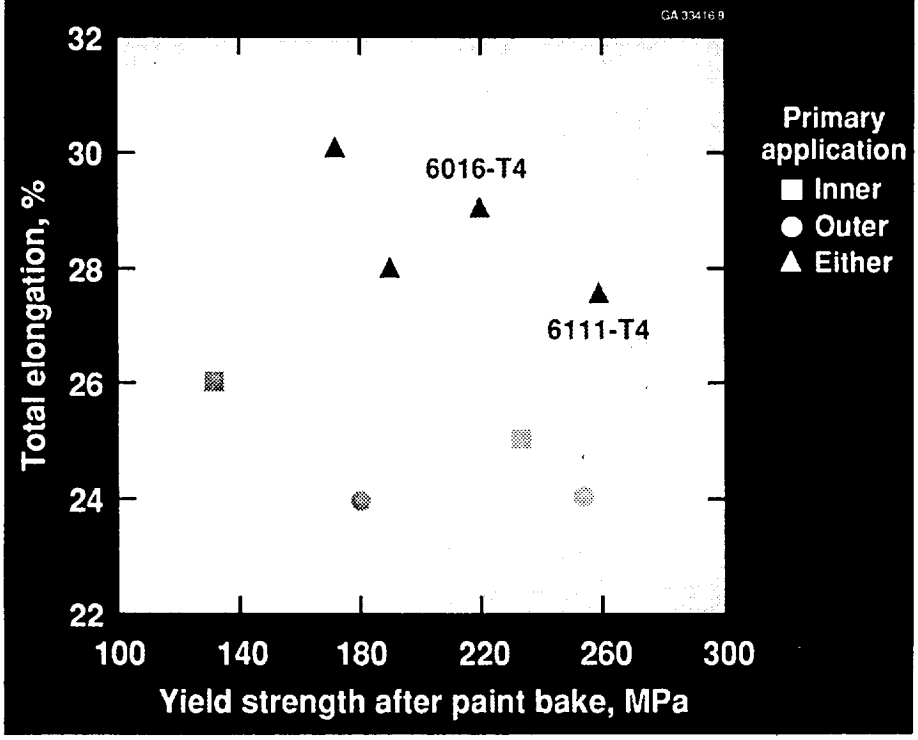
- Inner panels
  - Formable
    - Stretchable
    - Drawable
    - Hemmable
  - Alloys
    - 5XXX
    - 6XXX


Strength - Formability Relationships
for Aluminum Auto Body Sheet Alloys
GA 334165
32
30
28
26
24
22
Total elongation, %
5182-O
2036-T4
100
140
180
220
260
300
Yield strength after paint bake, MPa
Primary application
Inner
Outer


Strength - Formability Relationships
for Aluminum Auto Body Sheet Alloys
GA 33418 6
32
30
28
26
24
22
Total elongation, %
6009-T4
6010-T4
100
140
180
220
260
300
Yield strength after paint bake, MPa
Primary application
Inner
Outer


Strength - Formability Relationships
for Aluminum Auto Body Sheet Alloys
GA 33416-7
32
30
28
26
24
22
Total elongation, %
5030-T4
2008-T4
Primary
application
Inner
Outer
Either
100
140
180
220
260
300
Yield strength after paint bake, MPa

Strength - Formability Relationships for Aluminum Auto Body Sheet Alloys



Automotive

Emerging materials for hang-on components
- Near term
  - 2XXX and 6XXX low bake temperature
  - 5XXX Luder-free

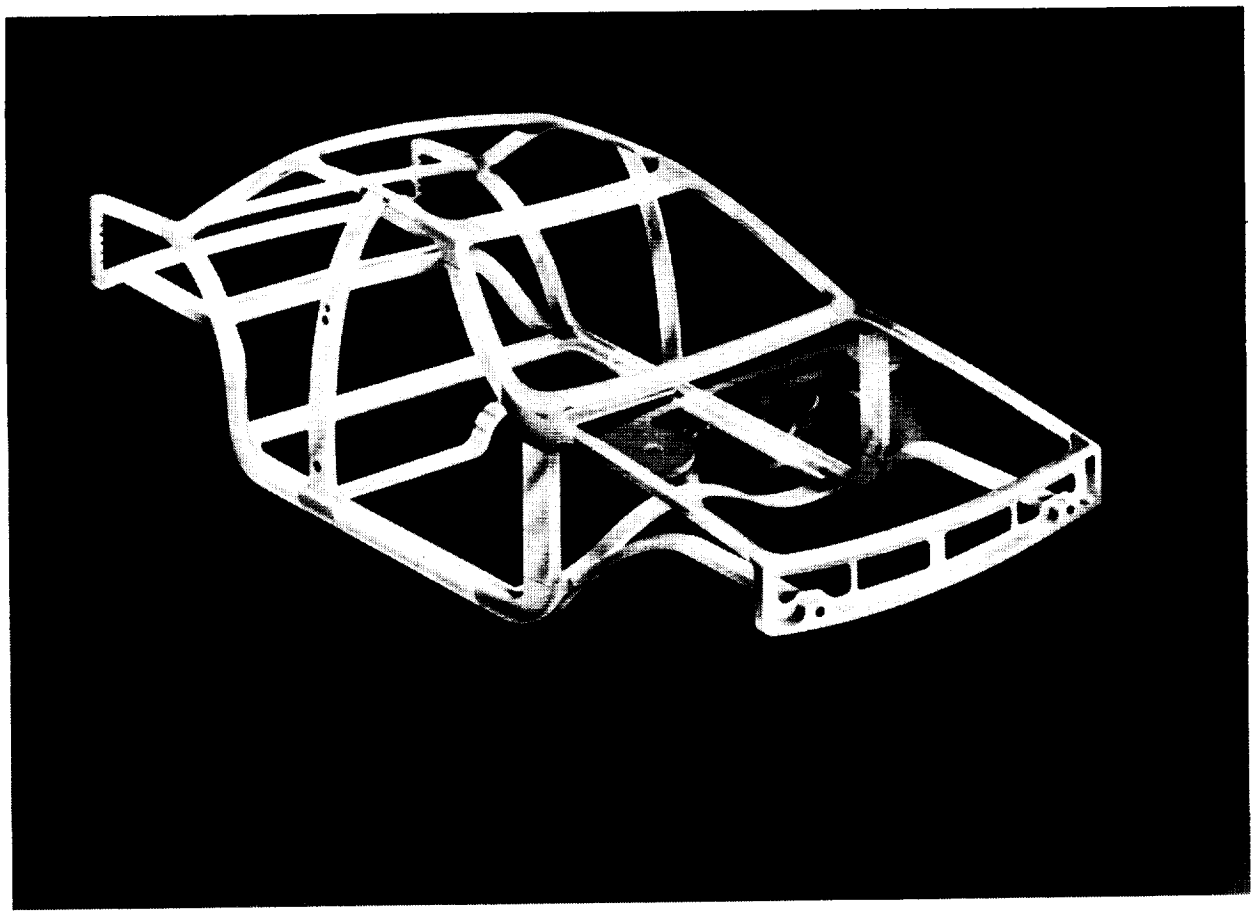
Automotive

Emerging materials for hang-on components

- Long term
  - Low cost
  - Formability, strength, weldability, and finish of best DQ steel
  - Corrosion resistance of best Al sheet

Automotive

Bumper components



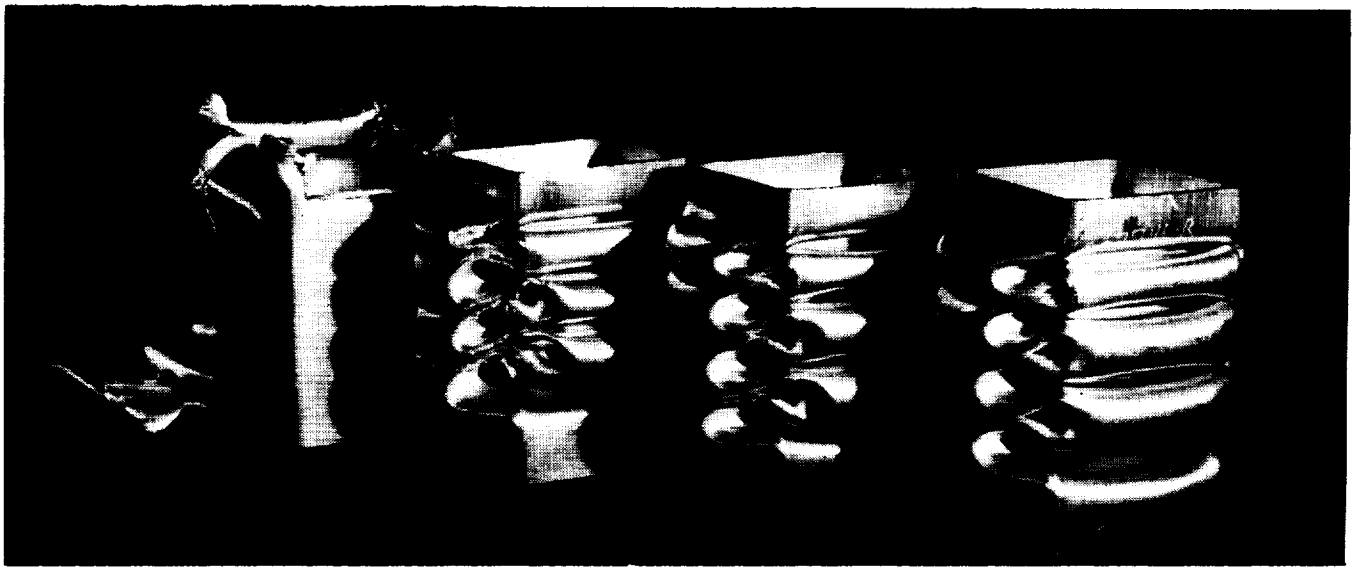
This rendering of a generic spaceframe illustrates the use of less than 100 aluminum extrusions and interconnecting aluminum die cast nodes which are robotically welded to form the car body. A limited number of aluminum sheet components (i.e. inner fenders, floor pan) are then attached to complete the body.

Automotive

- **Space Frame components**
  - Strong
  - Tough
  - Corrosion resistant
  - SCC resistant

Automotive

- **Space Frame components**
  - [illegible]
- Extrusions
  - Close tolerance 6XXX
  - Press quenched
  - Formed in T4
  - Aged to ~ 230 MPa YS
  - Crushable



Automotive

- **Space Frame components**
  - Strong
  - Tough
  - Corrosion resistant
  - SCC resistant
  - Extrusions
    - Close tolerance 6XXX
    - Press quenched
    - Formed in T4
    - Aged to ~ 230 MPa YS
    - Crushable
  - Die castings
    - Proprietary vacuum casting
      - < 5 ml gas/100g metal
      - Low porosity
    - High Si, low Mg
    - Fe to reduce die erosion and welding
    - SHT aged to T6
      - YS 115 to 140 MPa
      - 18 to 22% elongation
      - Crushable

Evolution of Aluminum Aerospace Alloys

New aluminum base alloys continue to be introduced

- 1920's - 2017, 2014
- 1930's - 2024
- 1940's - 7075
- 1950's - 7178, 7079, X2020
- 1960's - 7175, 7475, 2124
- 1970's - 7050, 7150, 2324
- 1980's - 2034, 2090, 8090, 2091
- 1990's - 7055, C188, ???
- 2000's - ???

Forces Shaping Future Aircraft Materials Needs

Many factors are driving change in 1990's:

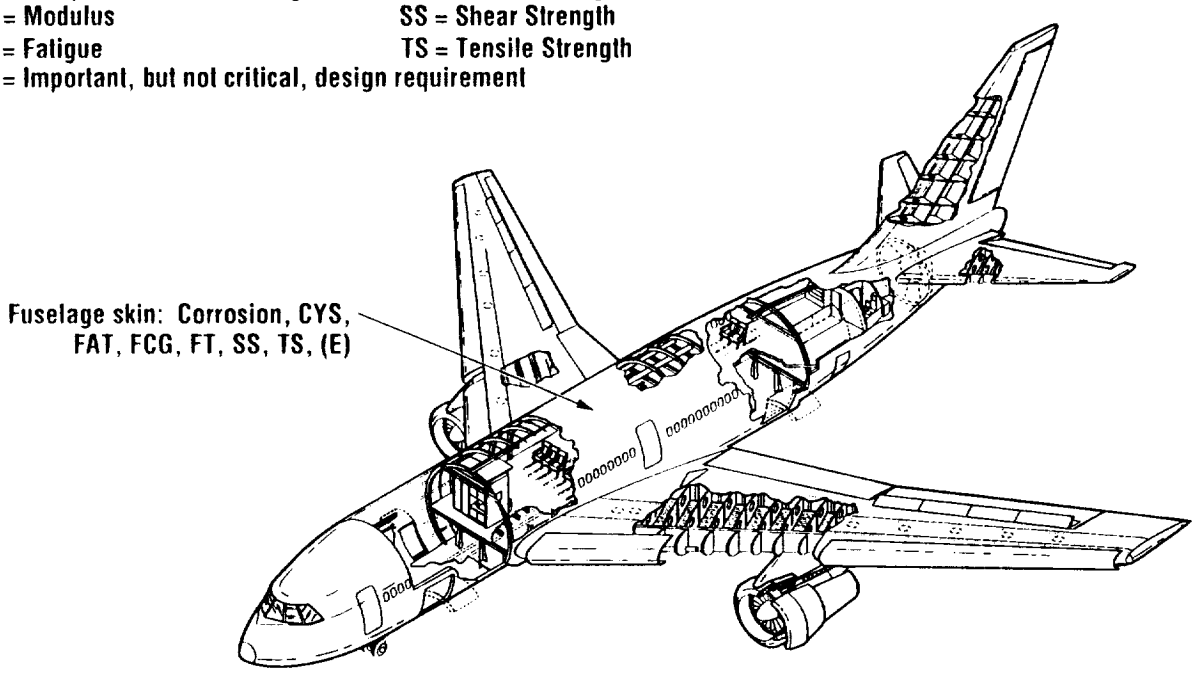
- Aging commercial fleet
  - ⇨ *fatigue, corrosion*
- Attention to cost effectiveness
  - ⇨ *procurement, inventory, manufacturing, operating*
- Fuel prices ???
  - ⇨ *incremental weight savings*
  - ⇨ *radical design/material changes*
- Future supersonic commercial aircraft
  - ⇨ *radical design change, high temperature*
- New competition

Property Requirements for Jetliner and Military Transport Applications

Material properties:

Corrosion	FCG = Fatigue Crack Growth
CYS = Compressive Yield Strength	FT = Fracture Toughness
E = Modulus	SS = Shear Strength
FAT = Fatigue	TS = Tensile Strength

( ) = Important, but not critical, design requirement



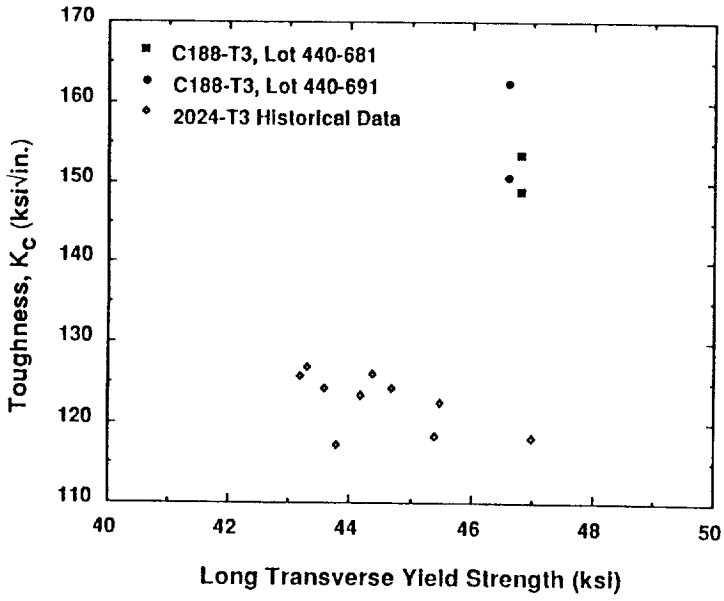
Fuselage

Skin

	Commercial and Transport	High Performance
Standard:	2024-T3 7475-T76 (thick)	7475-T76
Newly used:	2XXX-T3	
Being evaluated:	6013-T6 2091 8090 GLARE®	

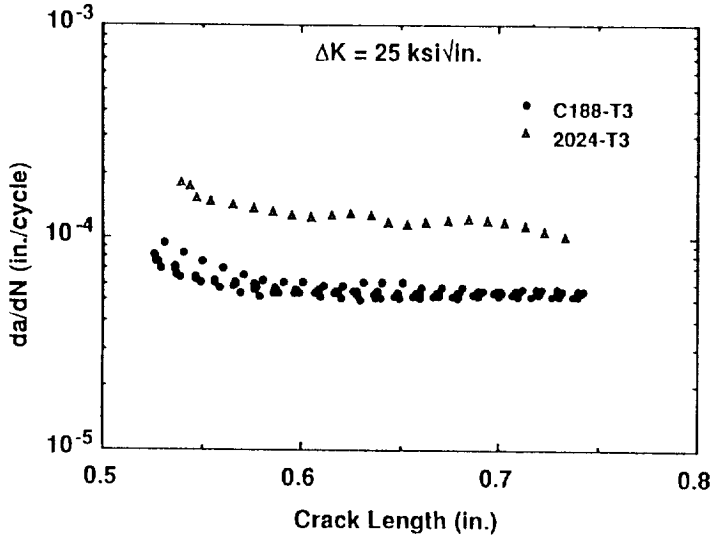
Toughness vs. Yield Strength:

Strength/toughness relationship for C188-T3 and 2024-T3 alclad sheet, 0.100 in. thick, T-L orientation. Toughness measured using 16 in. wide M(T) specimens.

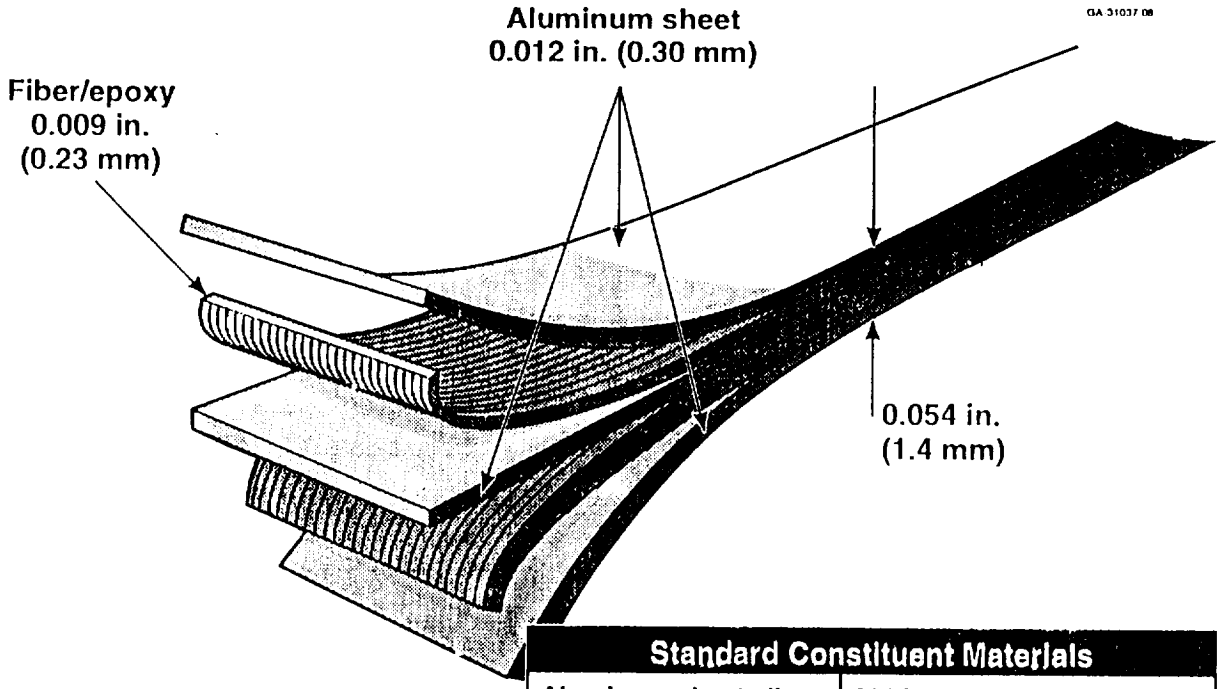


Constant ΔK Test:

Fatigue crack growth rate vs. crack length for C188-T3 and 2024-T3 alclad sheet tested at constant ΔK=25 ksi√in., R=0.1, T-L, high humidity (R.H.>90%) air.

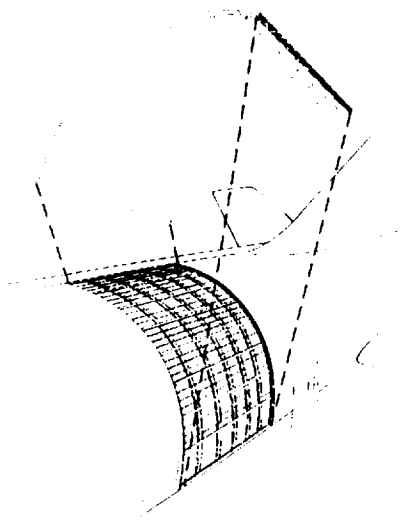


Fiber/Metal Structural Laminates
(Typical 3/2 Lay-Up Shown)



Standard Constituent Materials	
Aluminum sheet alloy	2024 and 7475
Fiber	Aramid and glass
Prepreg	Unidirectional and cross-ply

Fiber-Metal Laminates



Benefit: Weight Reduction
Application: Fuselage Skin
Target: 20 - 25%

Weight Reduction Because of:
- Density Reduction (10 - 15%)
- Downgaging Sheet Thickness (10%)
- Part Elimination (Doublers, Tear Straps)

Downgaging Possible Because of:
- Superior Fatigue Properties
- Excellent Damage Tolerance
  (Residual Strength, Fracture Toughness)

Property Requirements for Jetliner and Military Transport Applications

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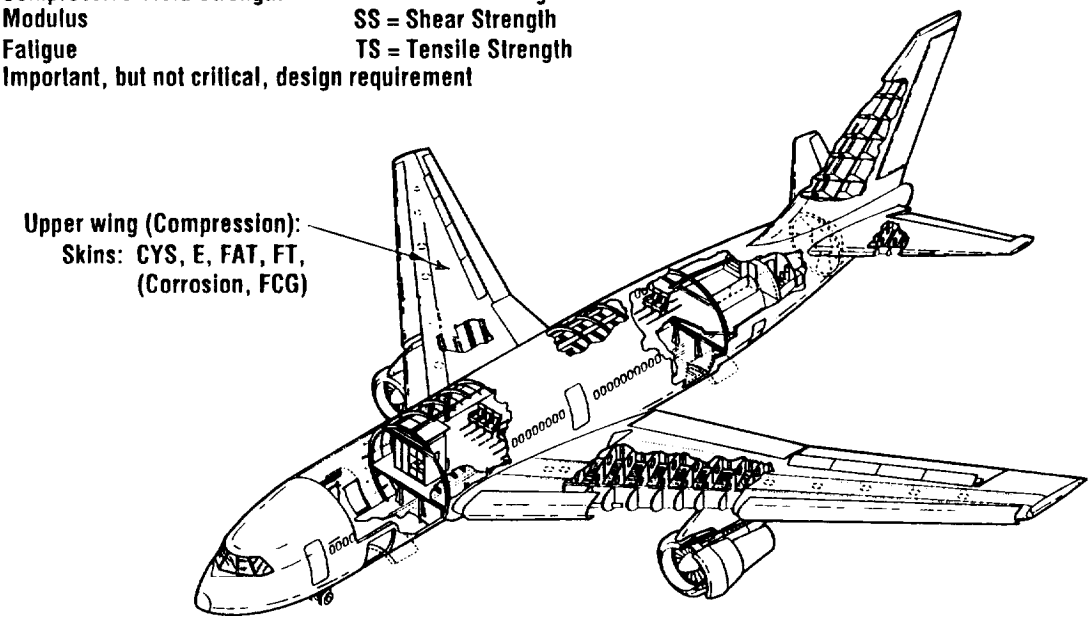
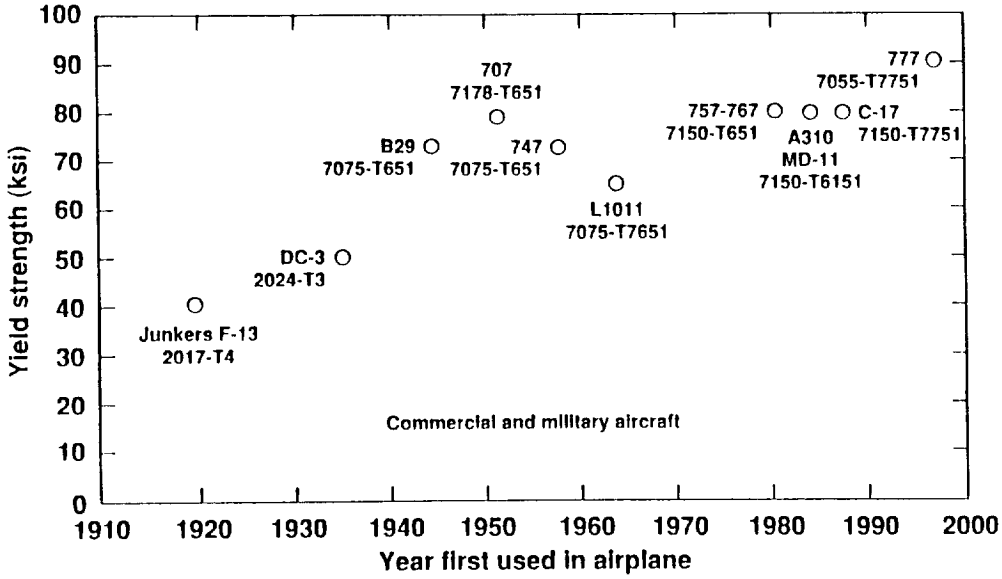


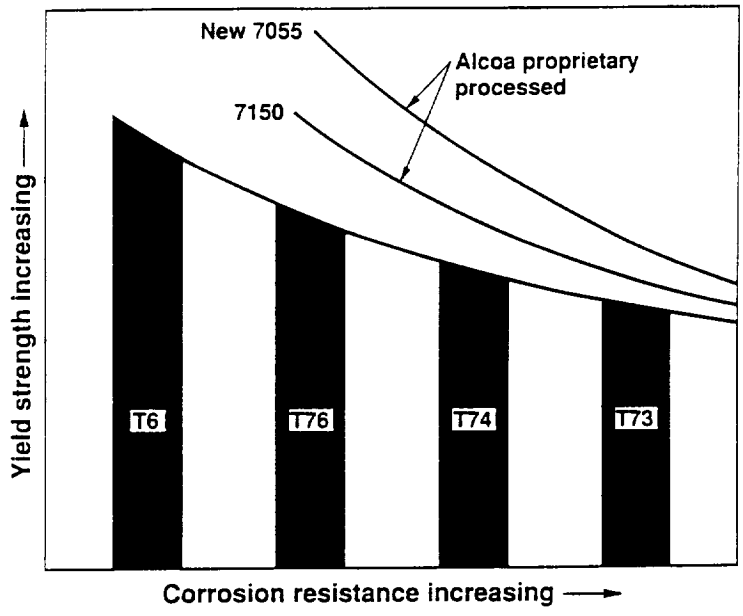
Wing

Upper Cover

	Commercial and Transport	High Performance
Standard:	7150-T6	7475-T73
	7150-T61	7050-T76
		2124-T8
Newly used:	7150-T77	
	7055-T77	
Candidates for development:	DRA	DRA
	Al-Gr	Al-Gr
	Al-Be	Al-Be
		CRA



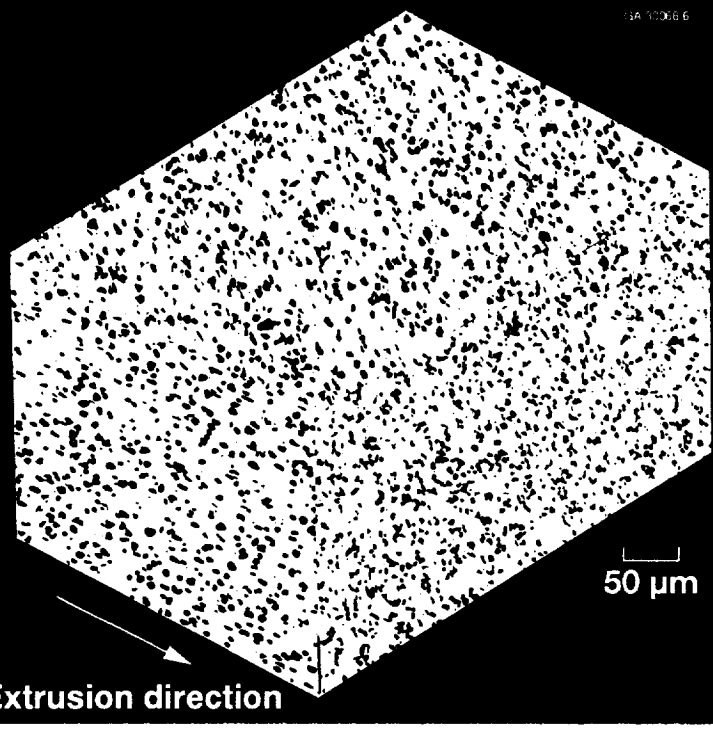
Upper Wing Skin Plate Alloy/Temper Chronology



Schematic Illustration of Strength/Corrosion Resistance Improvements of the New Alcoa Aluminum Alloy 7055 Compared to Aluminum Alloys 7150 and 7050

The DMMC Material Microstructure:

The P/M processing route can produce a reinforcement that is well-distributed in the aluminum matrix



Wing

Lower Cover

	Commercial and Transport	High Performance
Standard:	2024-T3 2324-T39 2224-T3	7475-T73 2419-T8
Being evaluated:	8090-T8 7475-T76	
Possible candidates:	ARALL	X7093-T73 Al-Li

Property Requirements for Jetliner and Military Transport Applications

Material properties:

Corrosion	FCG = Fatigue Crack Growth
CYS = Compressive Yield Strength	FT = Fracture Toughness
E = Modulus	SS = Shear Strength
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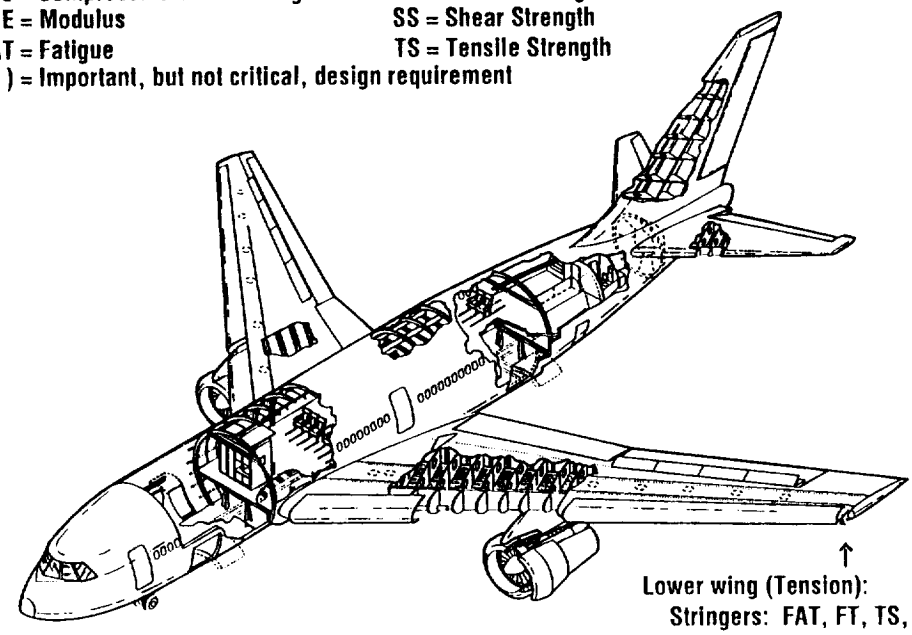

Lower wing (Tension):
Stringers: FAT, FT, TS, (Corrosion, FCG)