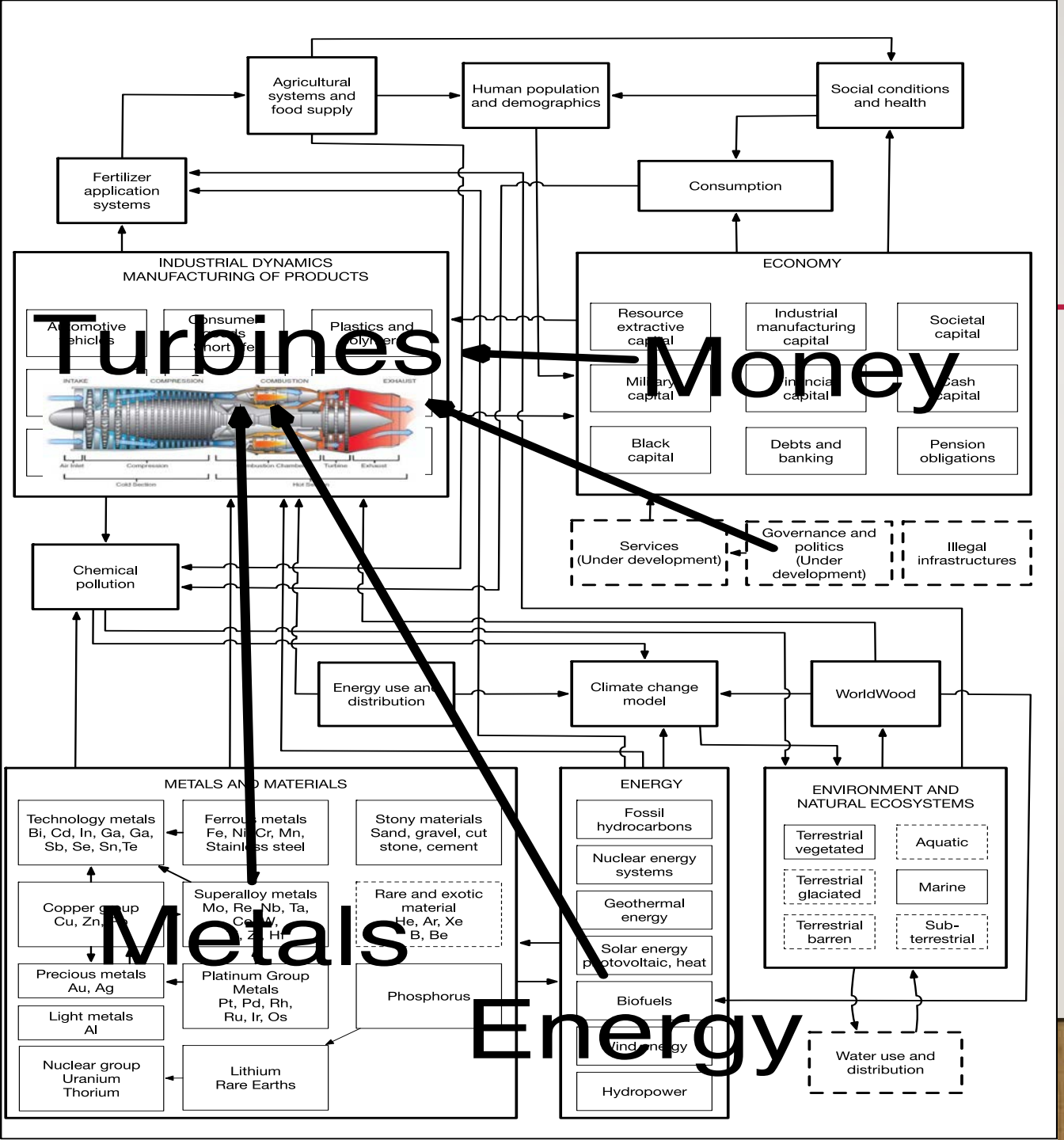
A SYSTEM DYNAMICS ASSESSMENT OF SUPPLY SUFFICIENCY FOR AEROSPACE TECHNOLOGY NEEDS USING THE WORLD6 MODEL

Peter Schlyter[1], Harald Sverdrup[2], Anna Hulda Ólafsdóttir[2],

[1]FACULTY OF INDUSTRIAL ENGINEERING, UNIVERSITY OF ICELAND, REYKJAVÍK, ICELAND
[2]INSTITUTE OF PHYSICAL GEOGRAPHY, UNIVERSITY OF STOCKHOLM, SWEDEN

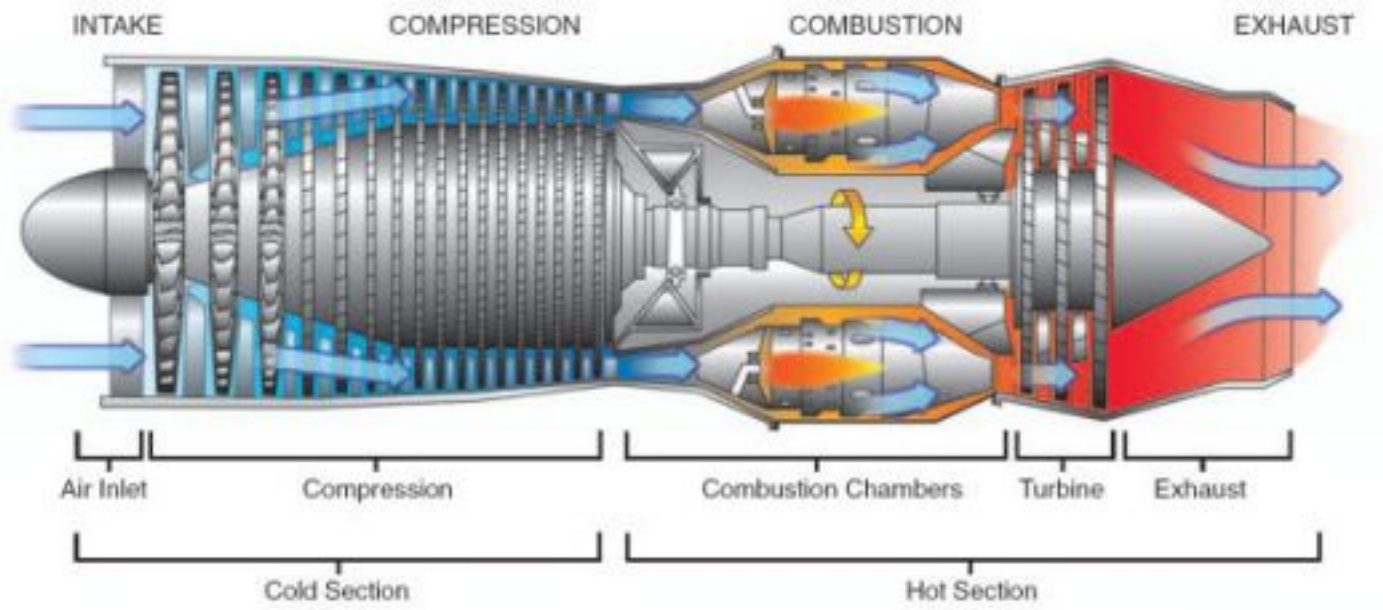


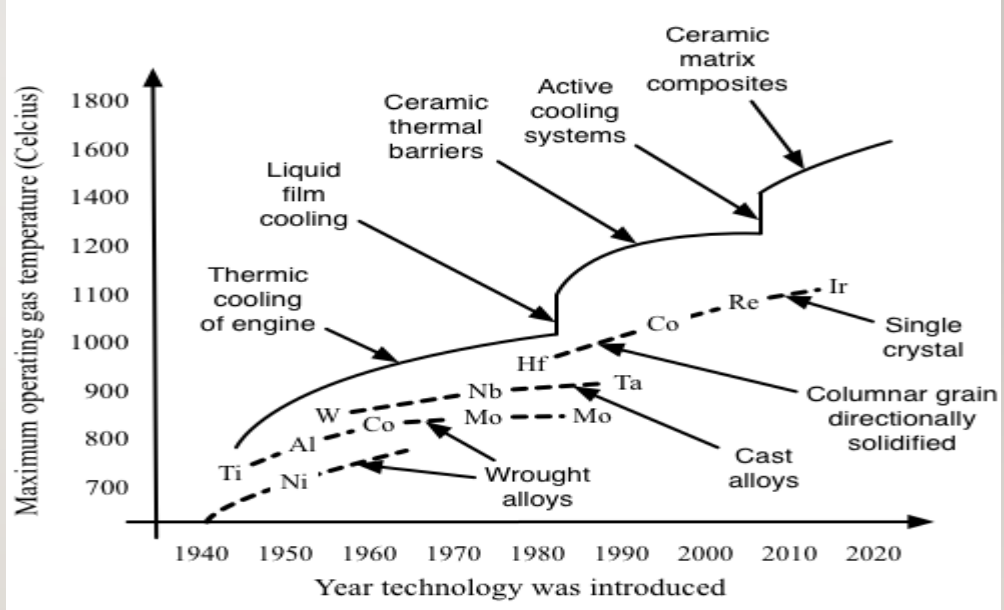
WORLD 6 MODEL WAS USED FOR AREOSPACE AND ENERGY CONVERSION NEEDS OF TURBINES

The WORLD6 model combines for this:

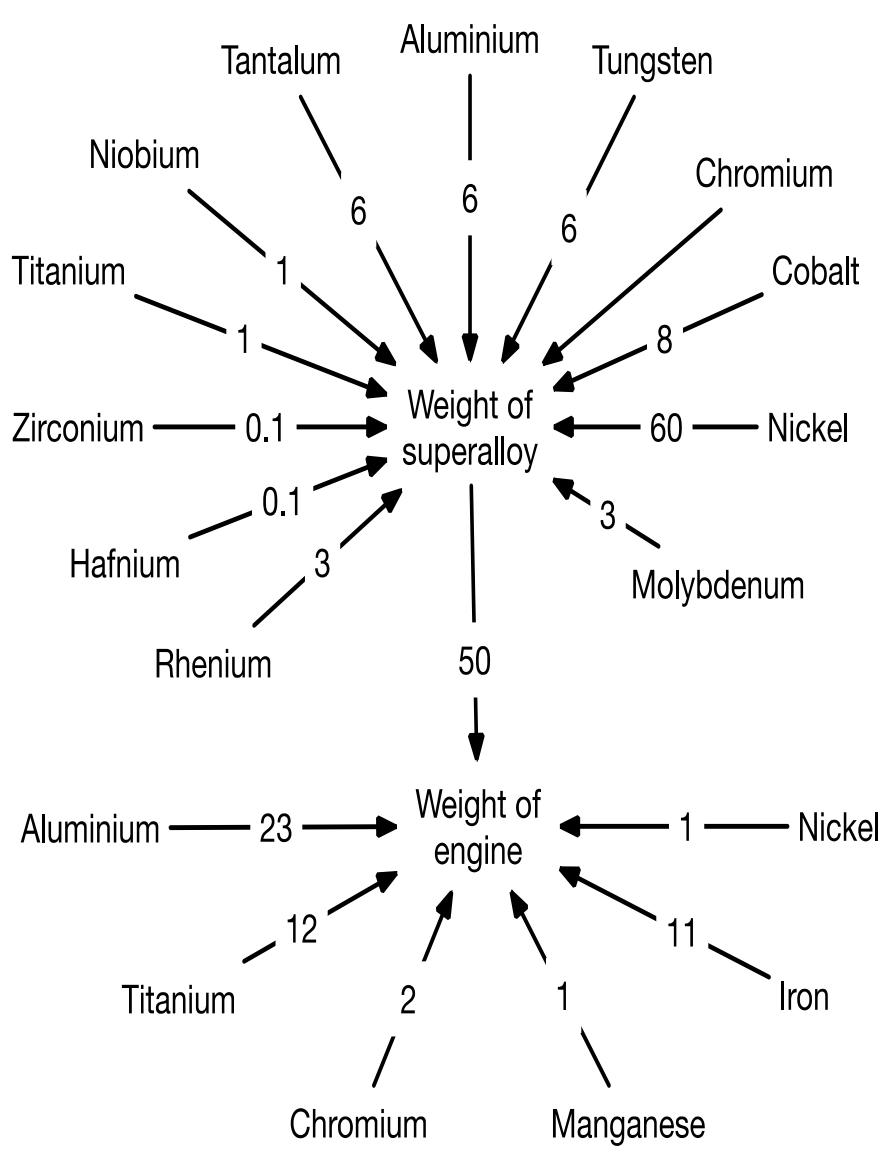
- Industrial dynamics and turbine and jet engine manufacturing
- Metal production, supply and markets
- Economy and finance
- Governance and military needs

HOT, CORROSIVE AND HIGH PRESSURES THE INSIDES OF HIGH PERFORMANCE JET ENGINES AND TURBINES

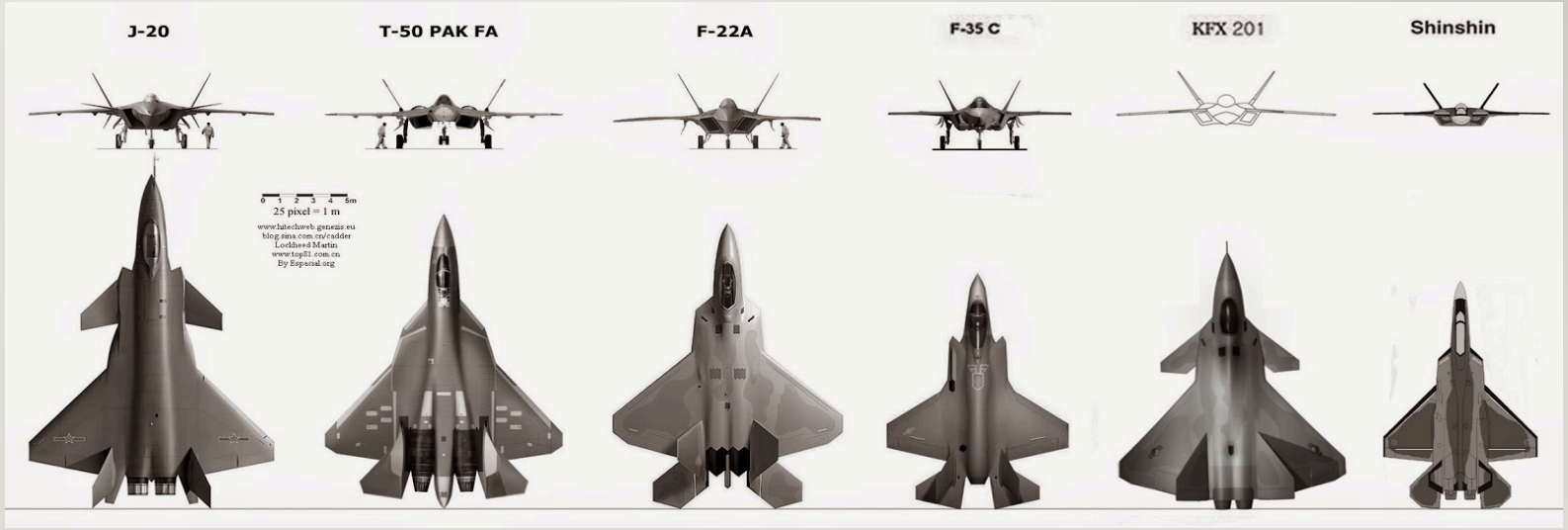




Summary of superalloy demand during the next 20 years (2017-2037), Ton of alloy.				
Item	Superalloy use, ton metal			
	Civilian aerospace	Military technology	Other use	Sum
Demand next 20 years	370,200	28,030	15,000	413,230
Annual demand	18,510	1,402	750	20,662



VERY MANY NEW AIRCRAFT ARE BEING PLANNED, BOTH CIVILIAN AND MILITARY



Need for individual metals for all technologies summarized.

Metal	Aviation super-alloys, ton/year	Power plant Turbines, ton/year	Chemical plants ton/year	Sum ton/year	Priority use	Annual total supply ton/year	% of annual supply	Risk for scarcity
Molybdenum	1,050	500	250	250,000 1,800	Stainless Superalloy	320,000	78 0.5	No
Rhenium	210	100	50	360 10	Superalloy Catalyst	80	450 13	Yes
Niobium	460	220	110	790 50,000	Superalloy Steel alloys	60,000	1 80	No Yes
Tantalum	210	100	50	1,000 360	Electronics Supoeralloys	1,400	72 26	Yes
Cobalt	2,100	1,000	500	3,600 120,000	Superalloys Batteries	60,000	6 200	Yes
Platinum	21	-	-	21 140	Superalloys Catalysts	180	12 80	Yes
Nickel	13,400	6,000	5,000	24,300 2,000,000 500,000	Superalloy Stainless Other	2,500,000	1 80 19	No Yes No
Titanium	2,730	1,000	4,000	7,730 250,000 10,000	Airframes Structural Medical	310,000	3 78 4	No
Zirconium	21	10	30	61	Nuclear	45,000	-	No
Hafnium	42	-	-	42	Superalloy	74	56	Yes
Wolfram	1,050	500	250	1,800 30,000	Superalloys Cutting tools	60,000	2 50	No
Chromium	2,500	1,500	1,500	5,500	Stainless	7,000,000	-	No
Aluminium	4,830	1,000	200	6,030	Structures	80,000,000	-	No
Manganese	210	100	100	410	Iron alloys	18,000,000	-	No
Iron	2,200	300,000	300,000	602,200	Structural	1,500,000,000	-	No

DO WE HAVE SUFFICIENT SUPPLY OF THESE METAL AVAILABLE?

CONCLUSION

- The metals rhenium, niobium, tantalum, cobalt, platinum, nickel and hafnium may come into aspects of scarcity in the future, with both higher prices and physical unavailability
- The recycling and conservation of these metals are at present insufficient and irreversible losses are not sustainable
- High performance turbines are important for converting combustable fuels and steam to motion with high efficiency and lower losses