



WeaponSystemSustainment@blogspot.com

Charlie Vono, Colonel USAF, (RET)

How a Confluence of
Historical Events, Unprecedented Challenges,
&
Remarkable Talent
Led to a
Systems Engineering-Based
Management Model
for
Sustaining Complex Systems

- Complete -

with a Survey of the History of Complex Systems and
with a Forecast of their Future

circa 1760 - 2060



Charlie Vono

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EDUCATION

- B.S. Astronautical Engineering, USAF Academy, 1976
- M.S. Systems Management, USC, 1985
 - Management Information Systems
 - Special studies under Dr. C.C. Crawford
- M.S. Mechanical Engineering, USU, 1995
- Air University, 1996

US AIR FORCE (colonel, retired 2008)

- KC-135 Aircraft Commander
- Inertial Upper Stage Software Systems Chief
- F-16 Battle Damage Repair Engineer
- Ogden Air Logistics Center Staff
- Pacific Command Reserve Forces Division Chief

TRW & NORTHROP GRUMMAN since 1985 (retired 2014)

- ICBM Engineer and Technical Manager, propulsion & guidance
- Weapon system sustainment expert

Other Interests

- AIAA, SAME, Utah Engineers Council Chair
- CSM Workshop Facilitator
- Husband of the Turtle Lady



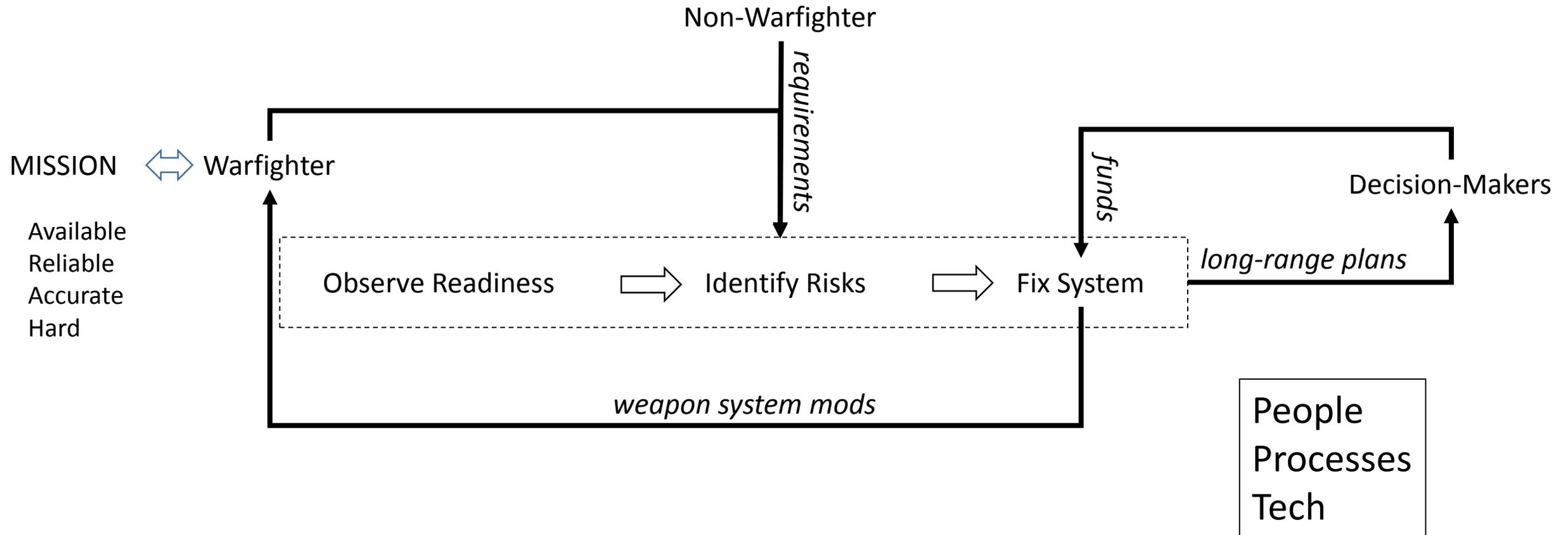
Today's Topic

- 1) A unique confluence of historical events, starting before the First Industrial Revolution, has led to
 - the proliferation of complex systems
 - that are increasingly being employed for longer and longer lifetimes
- 2) The trend in “1” can be expected to continue for decades and proliferate to many hundreds of non-military complex systems
- 3) A unique confluence of challenges and talent has led to the complex system sustainment management model which can be used to help the millions of people soon to be *trapped in “2”

*Most phone menus don't work correctly and Google Loon thinks they can sustain a world-wide network of internet balloons?



Weapon System Sustainment Management Model



Definitions

- Sustainment: Continuous, effective support of the system to ensure continued mission capability
- Mission: Reason the system was built
- Readiness factors: Metrics that allow the enterprise to measure their ability to support the mission
- System: Everything required for the mission.
- Self-improving: Anti-fragile. Management system can repair itself like a wounded or diseased person and build itself up in specific bones and sinew like an athlete.
- Complexity: Judgment call

Timeline of Inventors (Rise of the Machines)

1712 – Thomas Newcomen, steam engine
1733 – John Kay, flying shuttle
1745 – E.G. von Kleist, first **electrical capacitor**
1752 – Benjamin Franklin, **lightening rod**
1764 – James Hargreaves, spinning jenny
1768 – Richard Arkwright, spinning frame
1769 – James Watt, improved **steam engine**
1774 – Georges Louis Lesage, electric **telegraph**
1775 – Jacques Perrier, **steamship**
1776 – David Bushnell, submarine
1779 – Samuel Crompton, spinning mule
1780 – Gervinus, circular saw
1783 – Benjamin Hanks, self-winding clock
1783 – Henry Cort, steel roller
1784 – Andrew Meikle, threshing machine
1785 – Edmund Cartwright, **power loom**
1786 – John Fitch, **steamboat**
1790 – William Pollard, roves and spins cotton
1791 – John Barber, gas turbine
1791 – Early **bicycles**
1794 – Eli Whitney, **cotton gin**

1794 – Philip Vaughan ball bearings
1797 – Wittemore carding machine
1797 – Henry Maudslay precision lathe
1799 – Alessandro Volta, **battery**
1799 – Louis Robert Fourdrinier Machine
1800 – J.M. Jacquard, Jacquard Loom
1804 – Richard Trevithick, **locomotive**
1809 – Humphry Davy, arc lamp
1814 – George Stephenson, steam locomotive
1814 – Joseph Nicéphore Niépce photography
1825 – William Sturgeon, electromagnet
1829 – American, W.A. Burt, **typewriter**
1830 – Barthelemy Thimonnier, **sewing machine**
1831 – American, Cyrus McCormick, **reaper**
1831 – Michael Faraday, **electric dynamo**
1834 – Henry Blair, corn planter
1834 – Jacob Perkins, ether ice machine
1835 – Henry Talbot, calotype **photography**
1835 – Francis Pettit Smith, propeller
1835 – Charles Babbage, mechanical **calculator**
1836 – Samuel Colt, **revolver**
1837 – Samuel Morse, **telegraph**

1839 – Charles Goodyear, rubber vulcanization
Sir William Robert Grove, **hydrogen fuel cell**
1843 – Alexander Bain, facsimile
1845 – Elias Howe, sewing machine
Robert William Thomson, **pneumatic tire**
1851 – Isaac Singer, sewing machine
1852 – Henri Giffard, airship
1853 – George Cayley, manned glider
1854 – John Tyndall, fiber optics
1855 – Isaac Singer, sewing machine motor
1858 – Hamilton Smith, rotary washing machine
Jean Lenoir, internal combustion engine
1862 – Richard Gatling, **machine gun**
Alexander Parkes, plastic
1866 – Alfred Nobel, **dynamite**
Robert Whitehead, torpedo



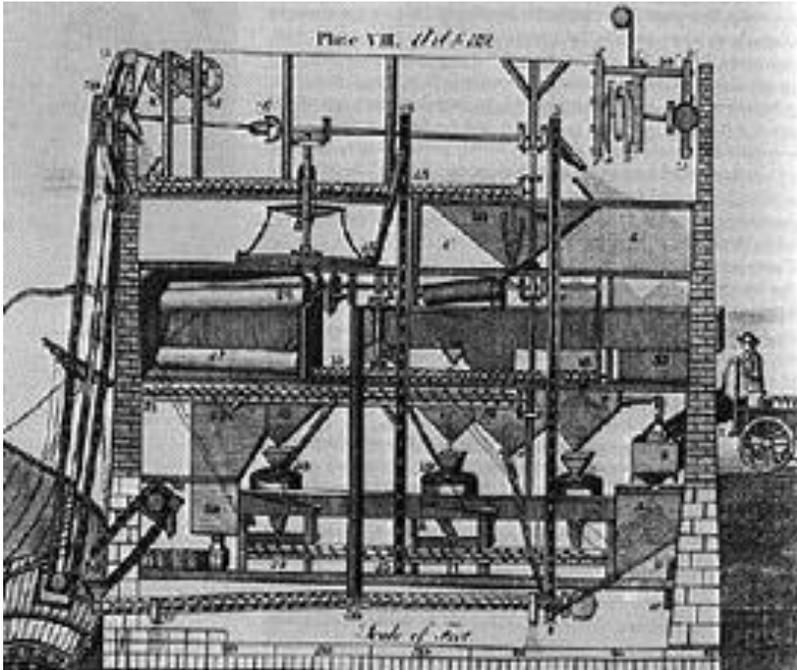
First Industrial Revolution

1760 to 1830

From hand work to machines

Factory system invented

- Transition to new manufacturing processes
- From hand production methods to machines
- New chemical manufacturing and iron production processes
- Improved efficiency of water power, the increasing use of steam power
- Development of machine tools and the rise of the factory system



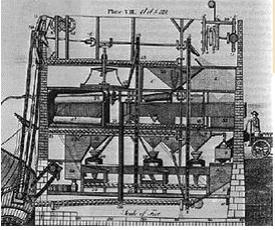
Evans Flour Mill 1780

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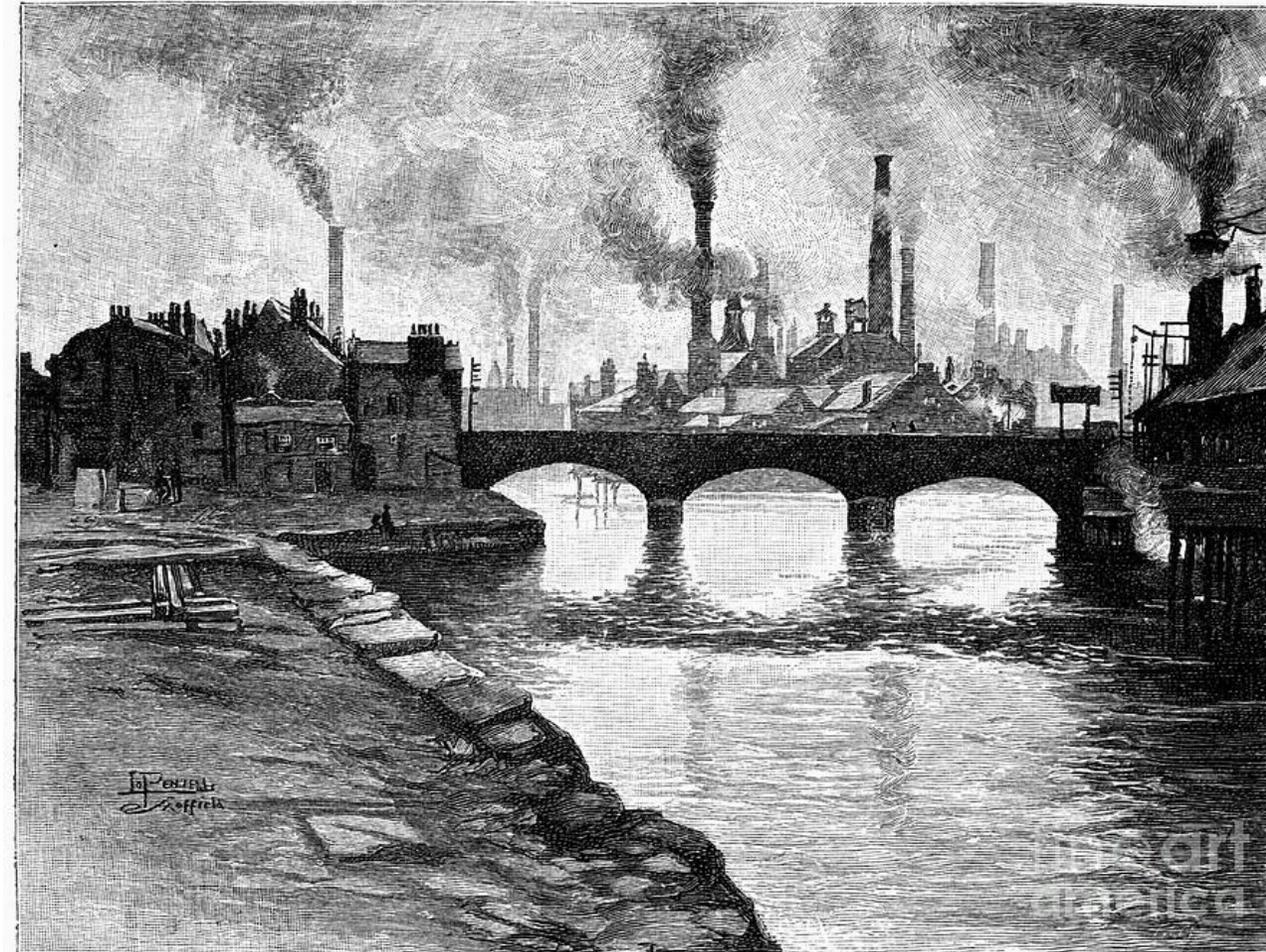


Second Industrial Revolution

1840 to 1870

Large factories, Steam power in transportation and factories

- Steam powered railways, boats, ships
- Large-scale manufacture of machine tools
- Steam powered factories



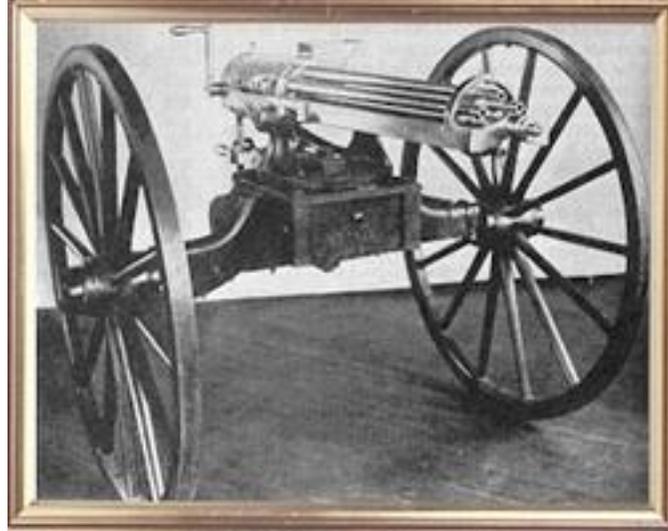
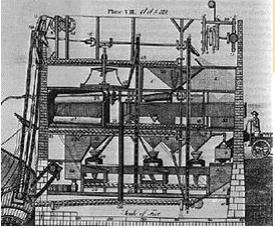
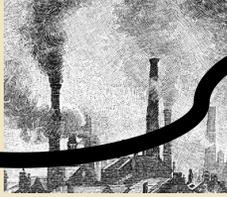
Fineartamerica.com

Sheffield, England, 1884 is a photograph by Granger

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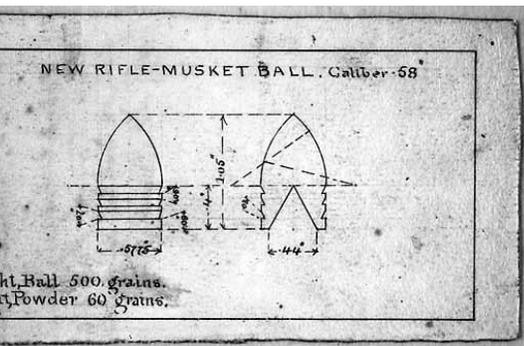
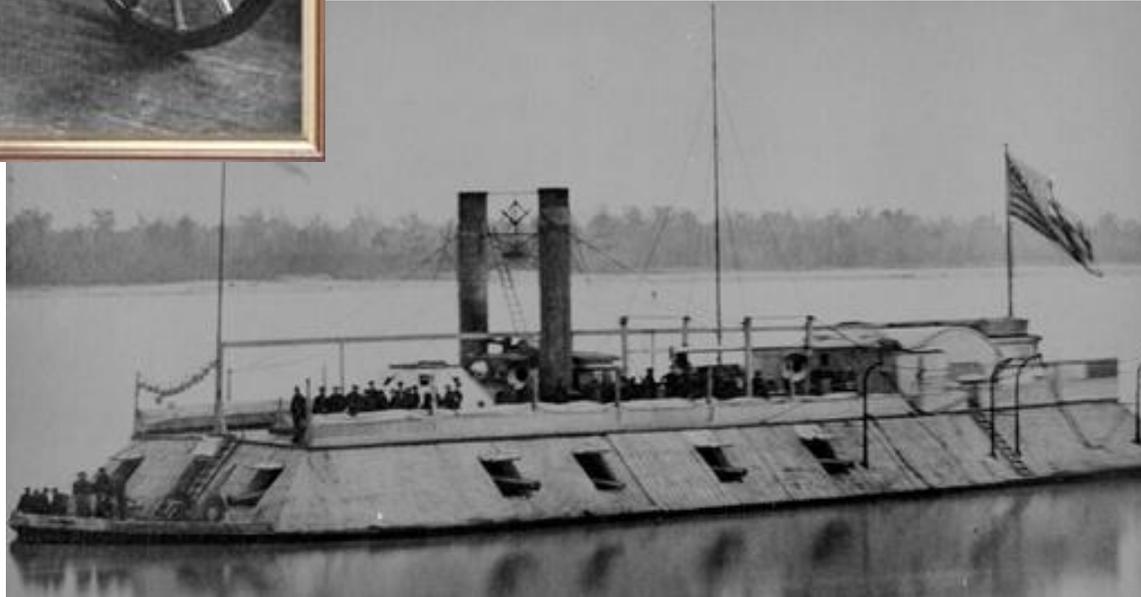
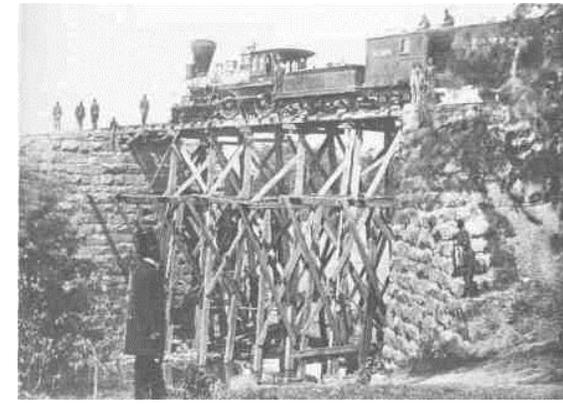
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Industrializing Warfare

1861 to 1865

American Civil War

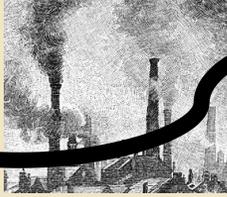
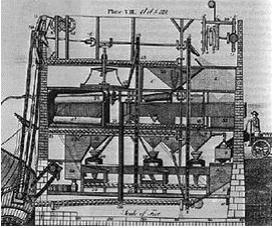
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Torpedoes, mines, rifled cannon, minie
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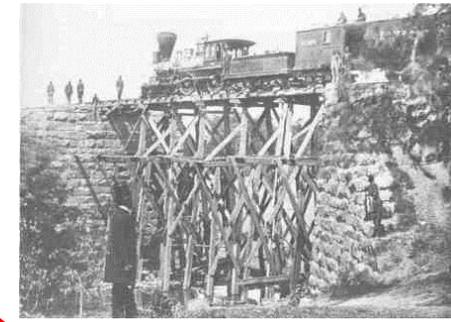


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WWI Trench Warfare

1914 - 1918

Machine guns and other efficient
killing machines



Strategic Bombardment

1930's Army Signal Corps Aviation Section
Air Doctrine

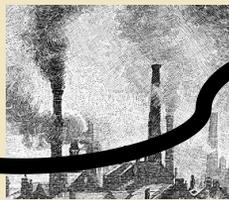
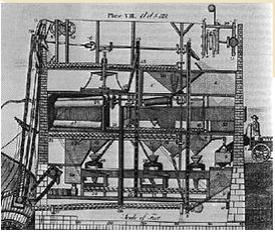
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A Confluence of Events

Machines became systems
Systems became complex systems
Complex systems remained in service longer and longer

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WWII Blitzkrieg

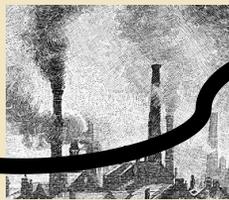
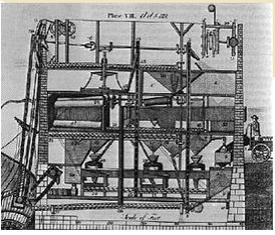
1939

ICBMs 1950 - present

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1760 to 1830

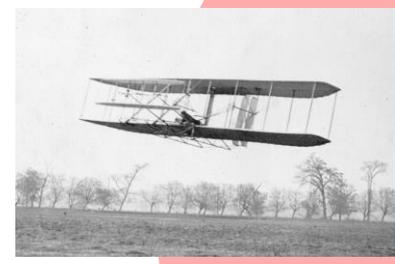
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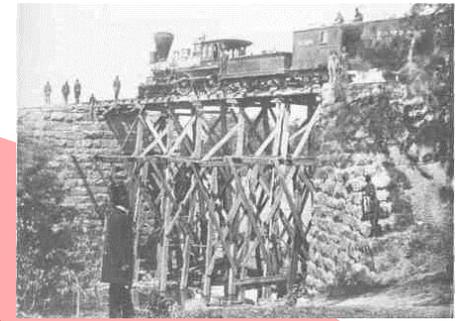


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1861 to 1865

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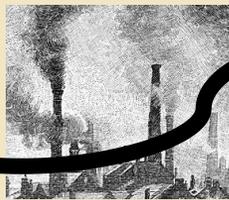
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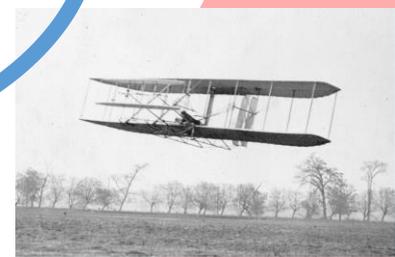
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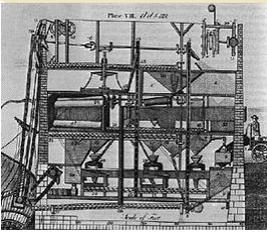
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Industrializing Nations

1880 to 1950

Telephones

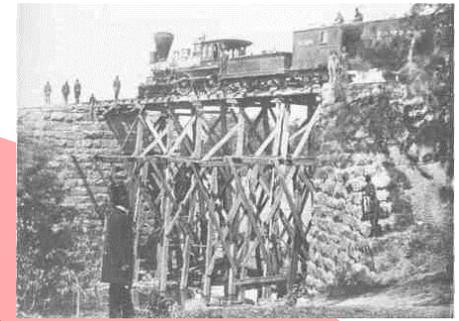


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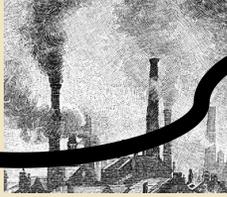
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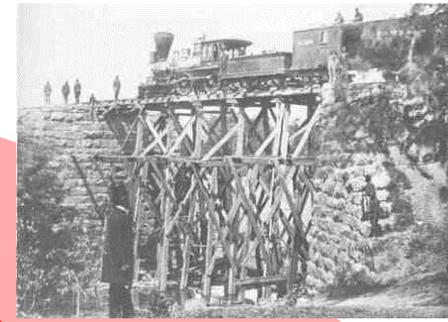


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1861 to 1865

American Civil War

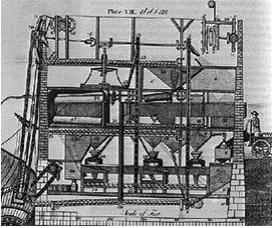
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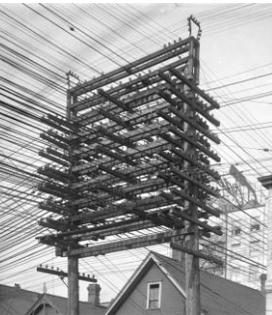
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Bell Labs

1940

Invention of Systems
Engineering



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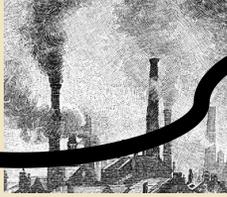
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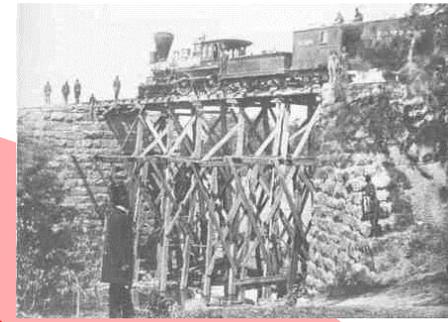


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1861 to 1865

American Civil War

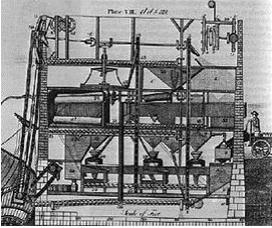
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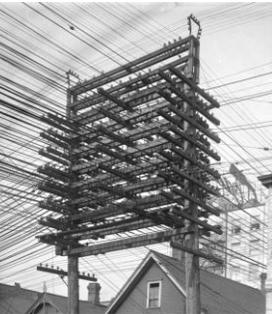
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USC Systems Management

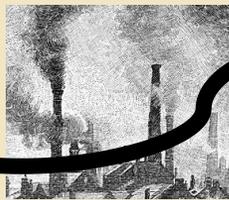
1952 to 1992

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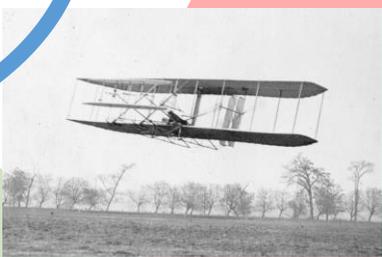
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Second Industrial Revolution

1840 to 1870

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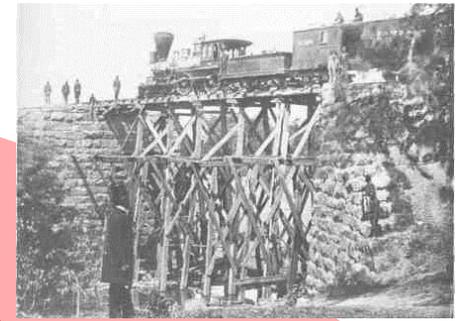


Industrializing Warfare

1861 to 1865

American Civil War

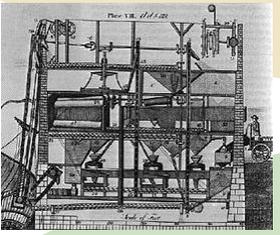
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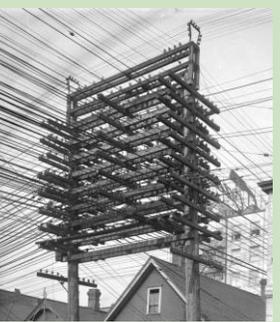
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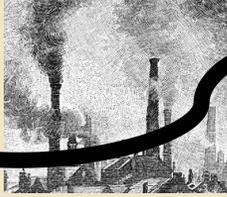
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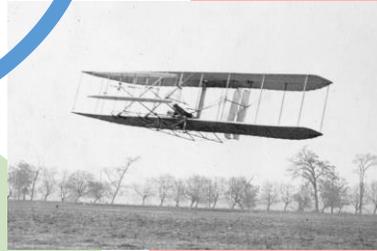
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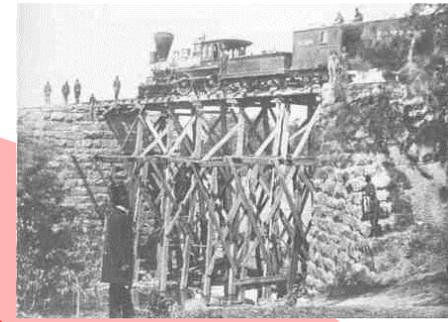


Industrializing Warfare

1861 to 1865

American Civil War

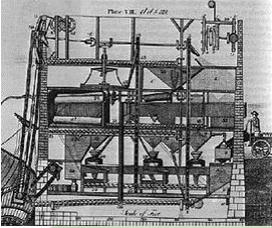
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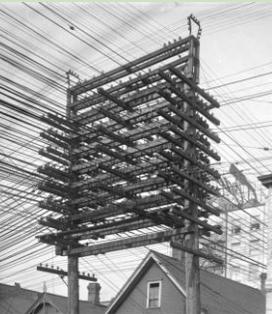
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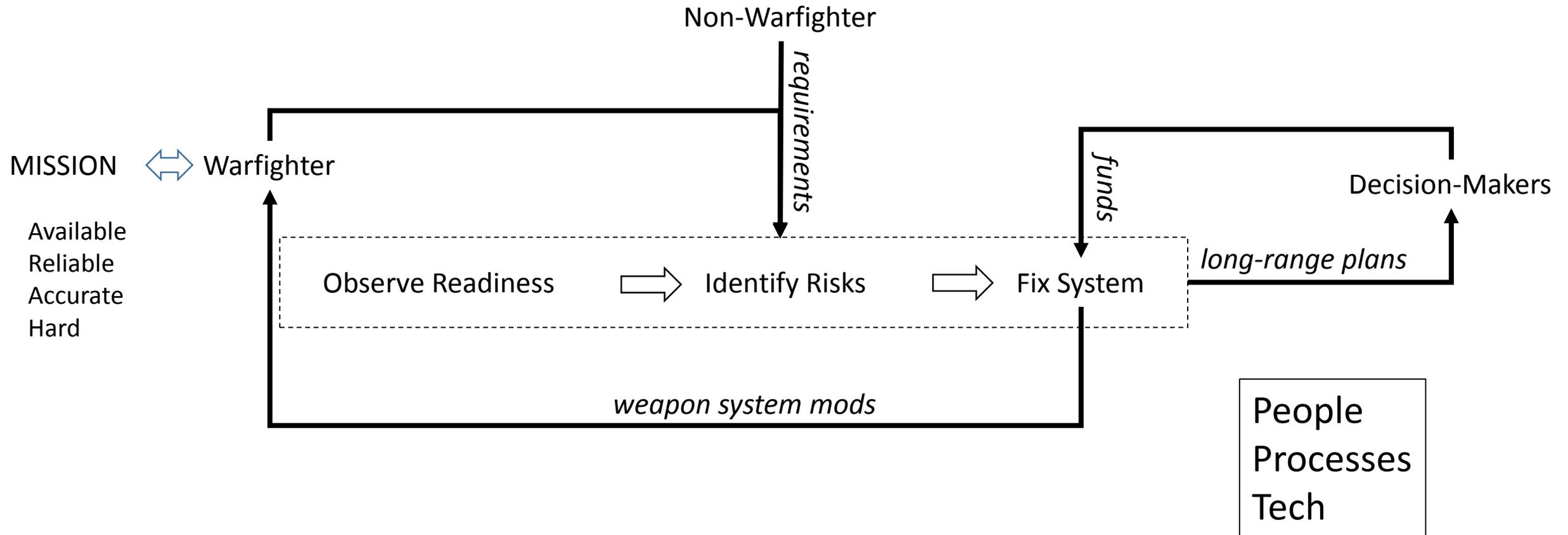
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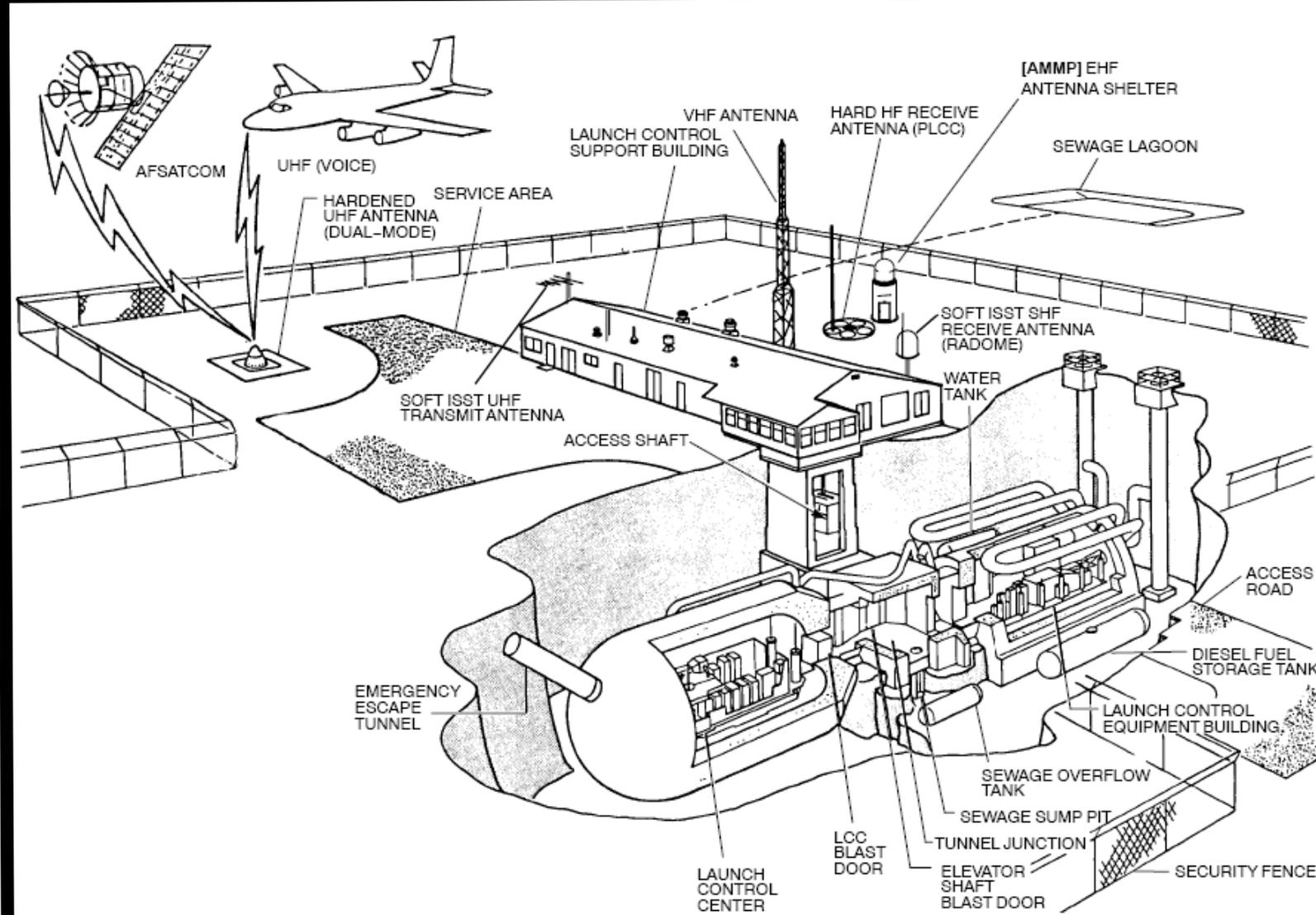
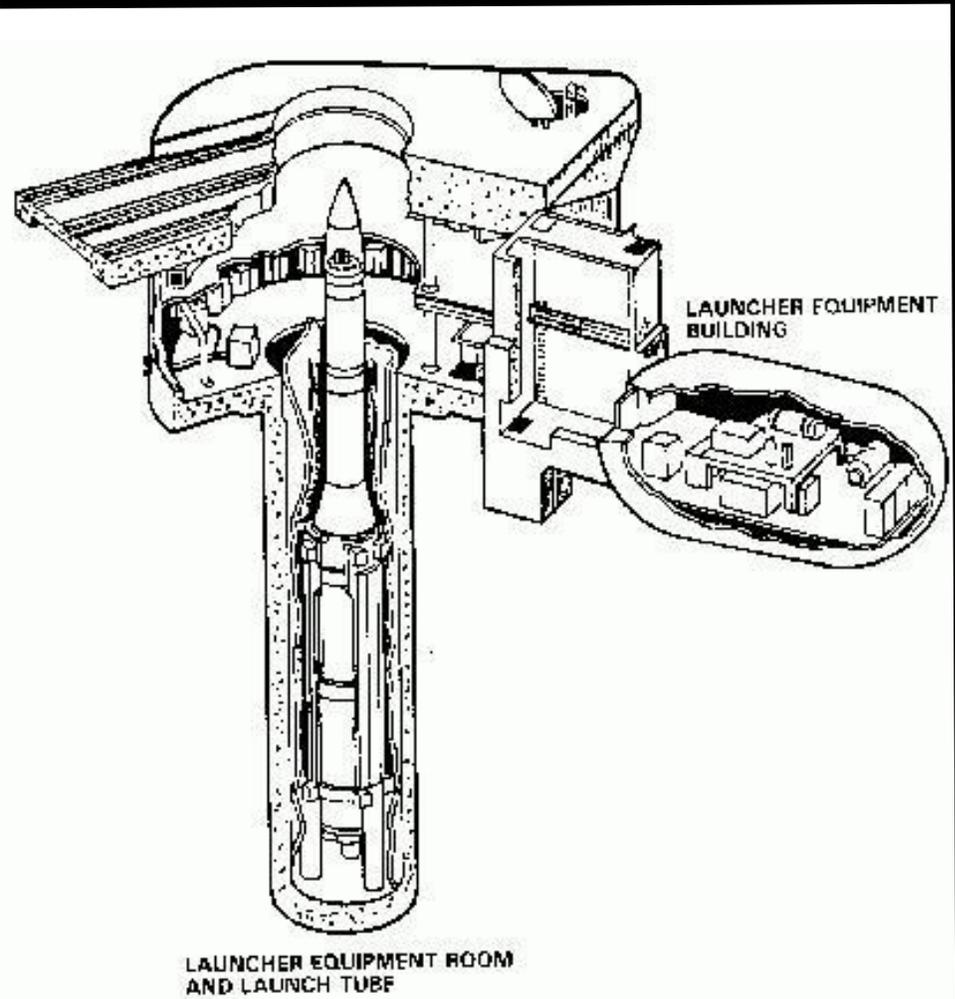
ICBMs 1950 - present



Weapon System Sustainment Management Model

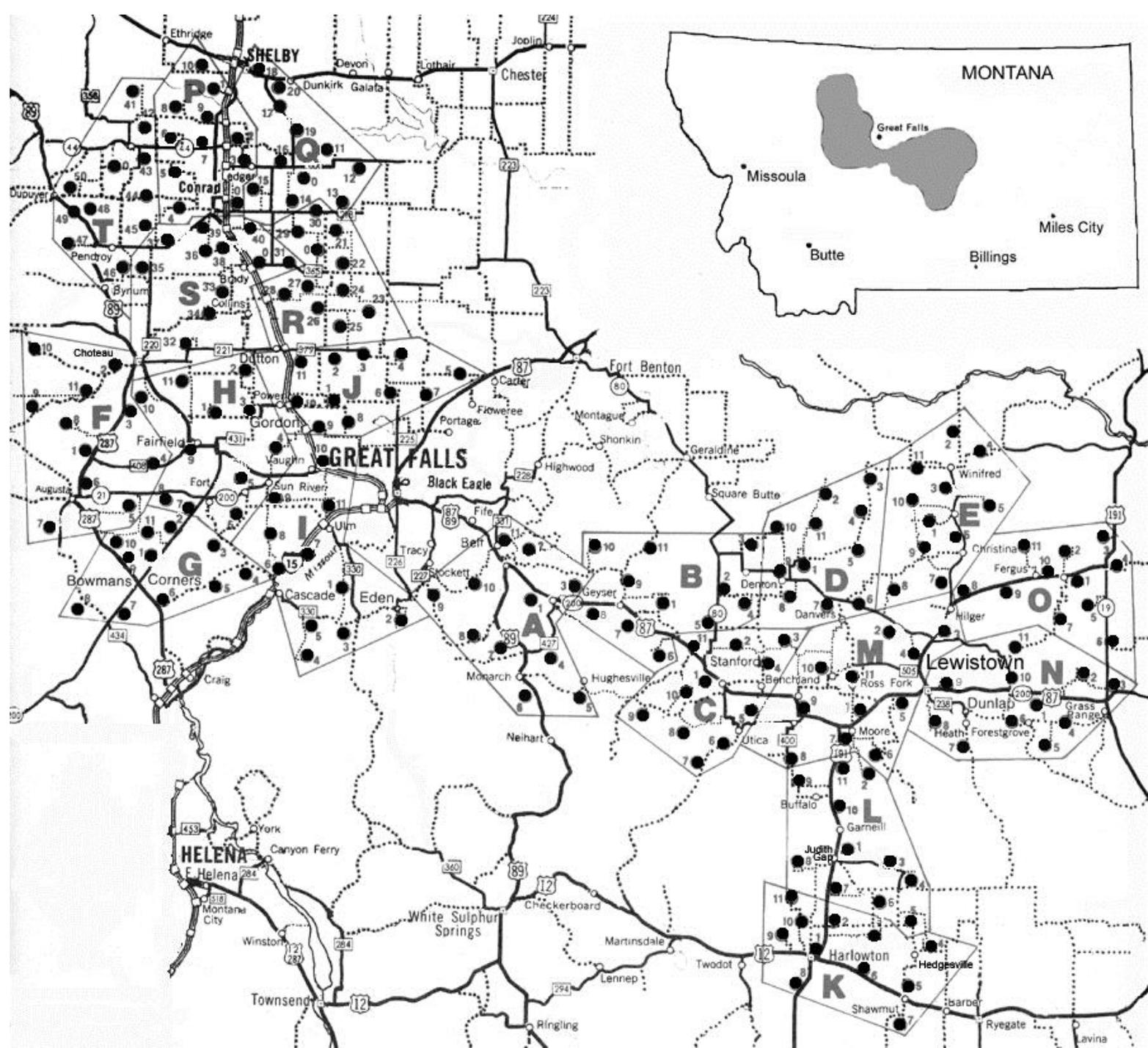


Minuteman ICBM Weapon System is Complex



...and Vast

- Repair Depots
- Supply Chains
- Test Equipment
- People
- Training Devices
- Industrial Base



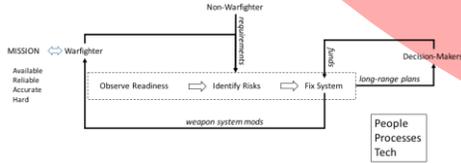
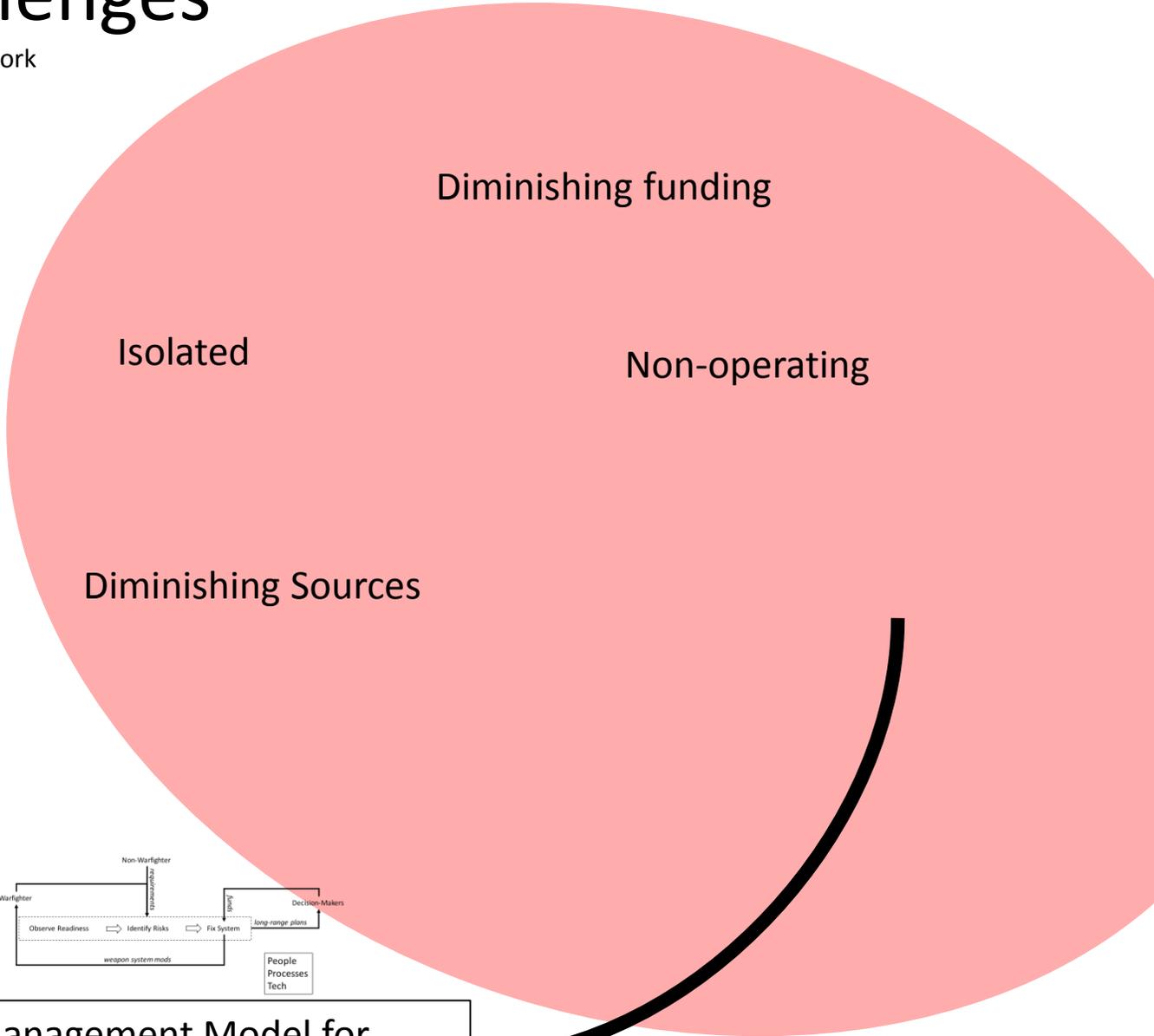
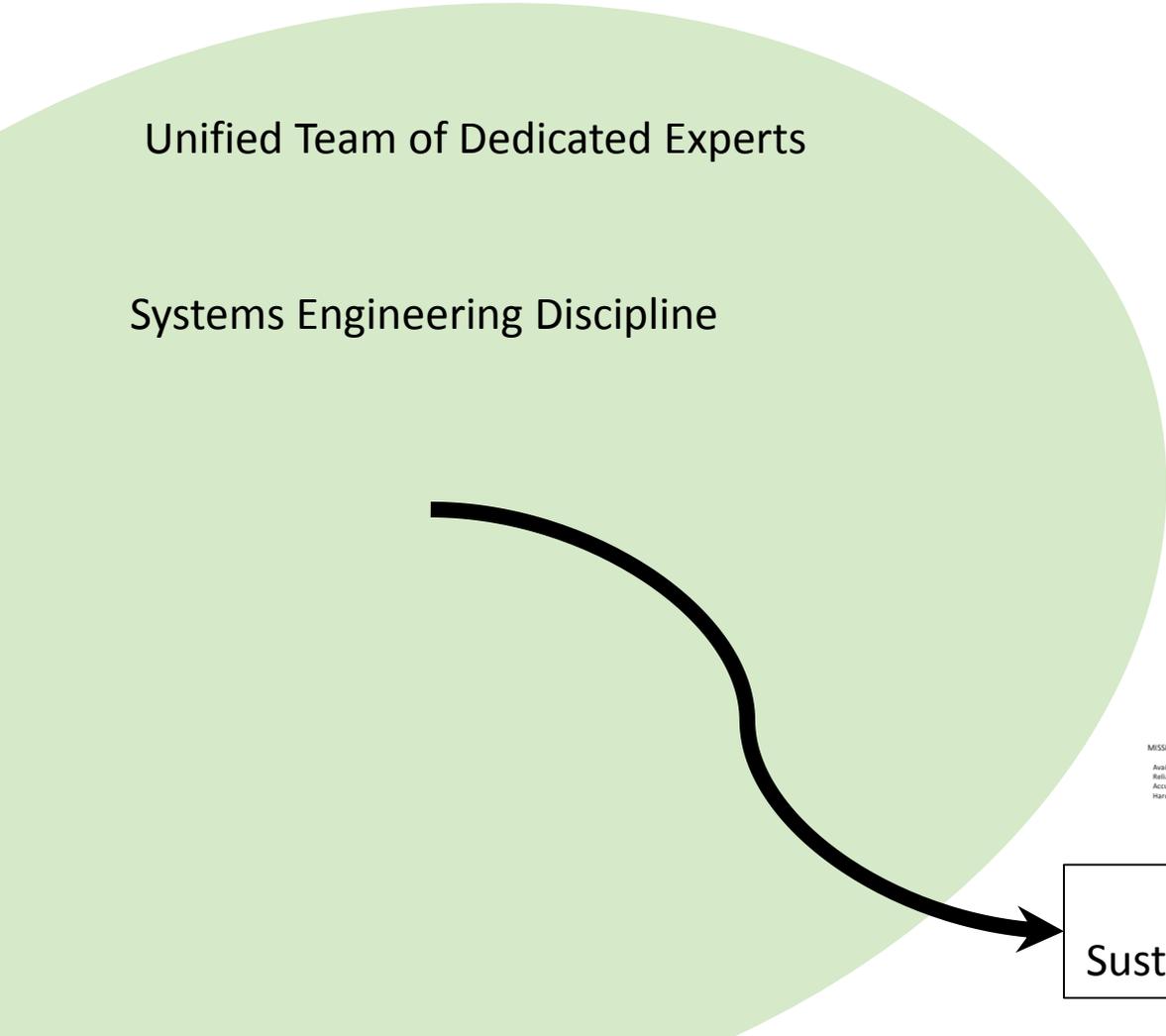
Minuteman ICBM Weapon System is also....

- Secure
- Prone to Diminishing Resources
- Essential



A Confluence of Talent & Challenges

ICBMs became the most difficult complex system that absolutely had to work

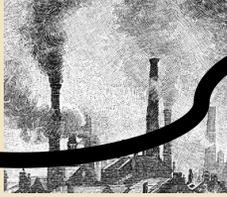


Management Model for Sustainment of Complex Systems

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1760 to 1830

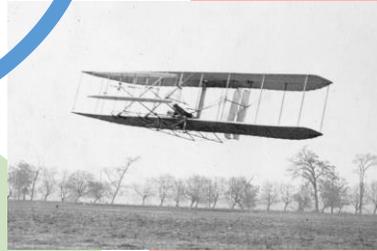
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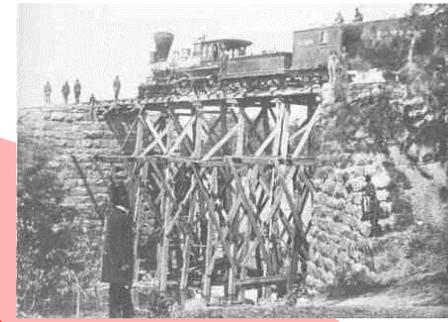


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1861 to 1865

American Civil War

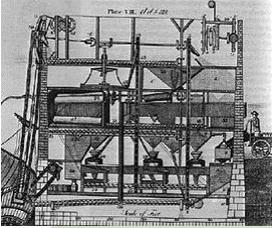
Trains, Railroads, Telegraph, Photography,
Torpedoes, mines, rifled cannon, minie
ball, underwater ships, iron clad ships,
manned balloons, ambulance corps



Industrializing Nations

1880 to 1950

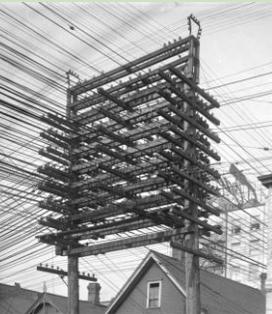
Telephones



Bell Labs

1940

Invention of Systems
Engineering



A Confluence of Events

Machines became systems
Systems became complex systems
Complex systems remained in service longer and longer

WWI Trench Warfare

1914 - 1918

Machine guns and other efficient
killing machines



Strategic Bombardment

1930's Army Signal Corps Aviation Section
Air Doctrine

Spanish Civil War

1936 - 1939

WWII Allies Strategic Bombardment

1941 to 1946

WWII Blitzkrieg

1939

USC Systems Management

1952 to 1992

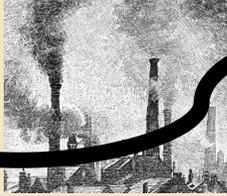
ICBMs 1950 - present



First Industrial Revolution

1760 to 1830

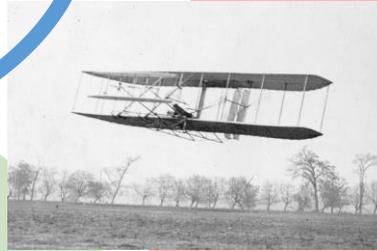
From hand work to machines
Factory system invented



Second Industrial Revolution

1840 to 1870

Large factories, Steam power in
transportation and factories

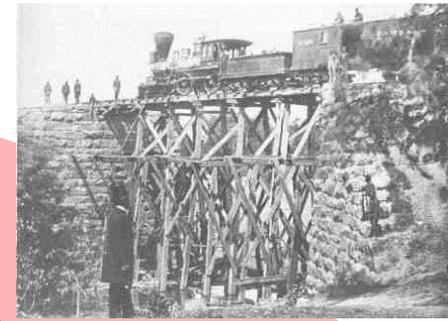


Industrializing Warfare

1861 to 1865

American Civil War

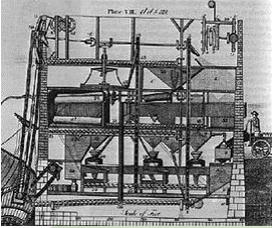
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1950s Race to Space

1960 to now, Exploit Space

2010 to 2060 Commercial LEO

Building Stuff in the Year 2062

- Computer Intelligence
 - Non human intelligence
 - Huge volumes of disparate data
 - Altair-like structures
 - Optimal construction paths
- A Few, Small Building Blocks
 - No supply chains
- Robot Construction
 - Autonomous
 - Non-human skill sets
 - Robots are the tooling – M Blocks
 - Robots making robots
- Non-engineers creating via trying



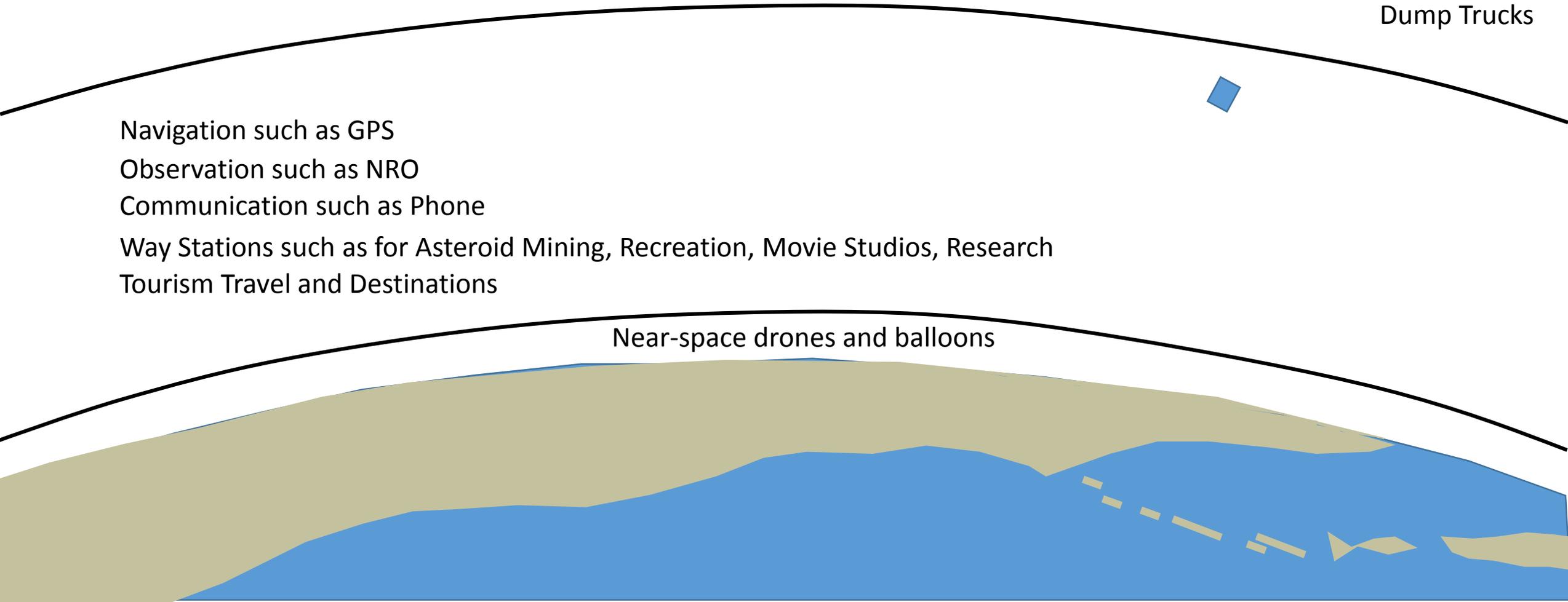
The Year 2060: LEO Capitalism

Singletons and Swarms

Navigation such as GPS
Observation such as NRO
Communication such as Phone
Way Stations such as for Asteroid Mining, Recreation, Movie Studios, Research
Tourism Travel and Destinations

Near-space drones and balloons

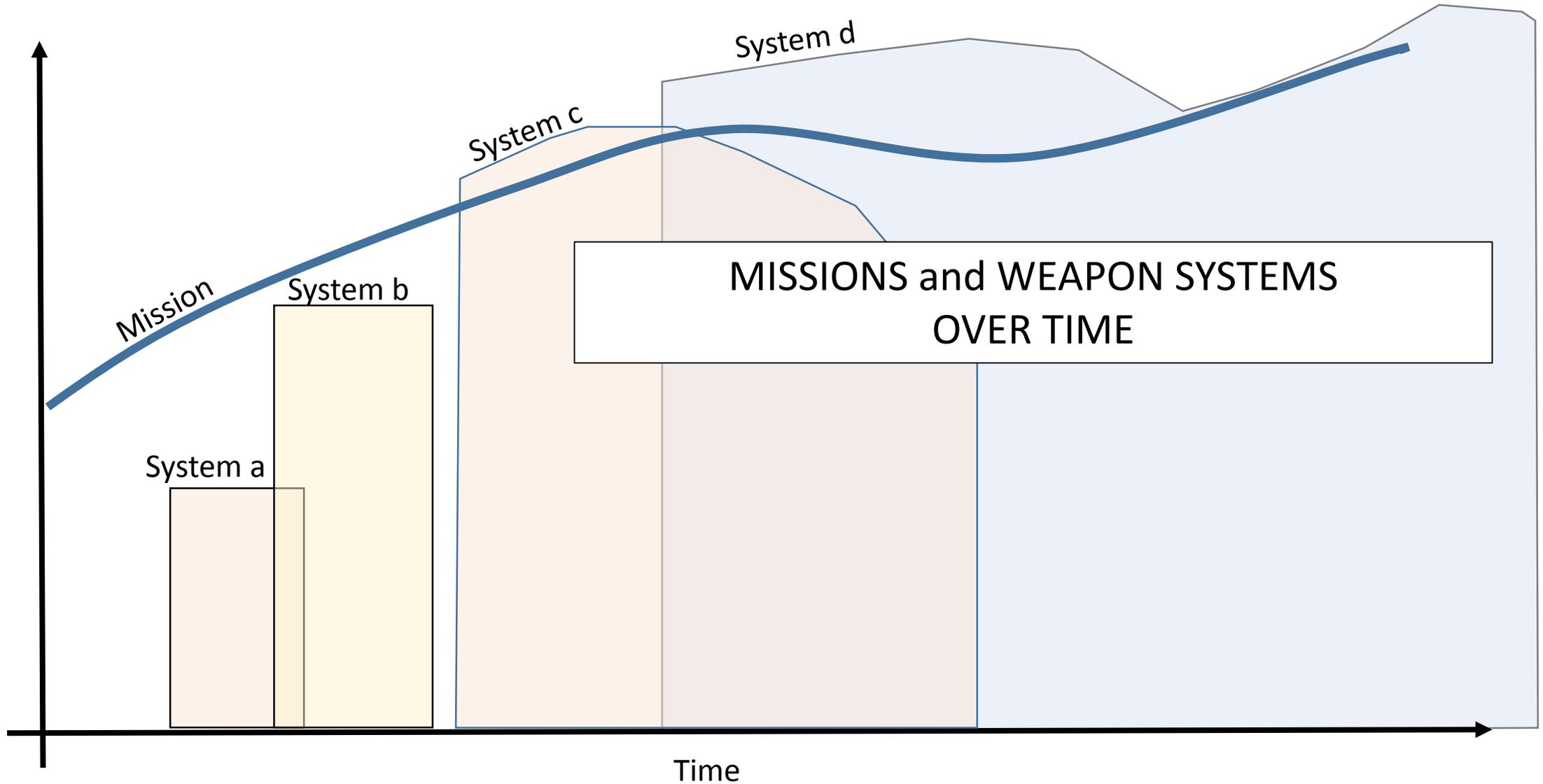
Fixers
Grabbers and movers
Refuelers
Refueling Depots
Factories
Raw Materials Warehouses
Finished Devices Warehouses
Dump Trucks



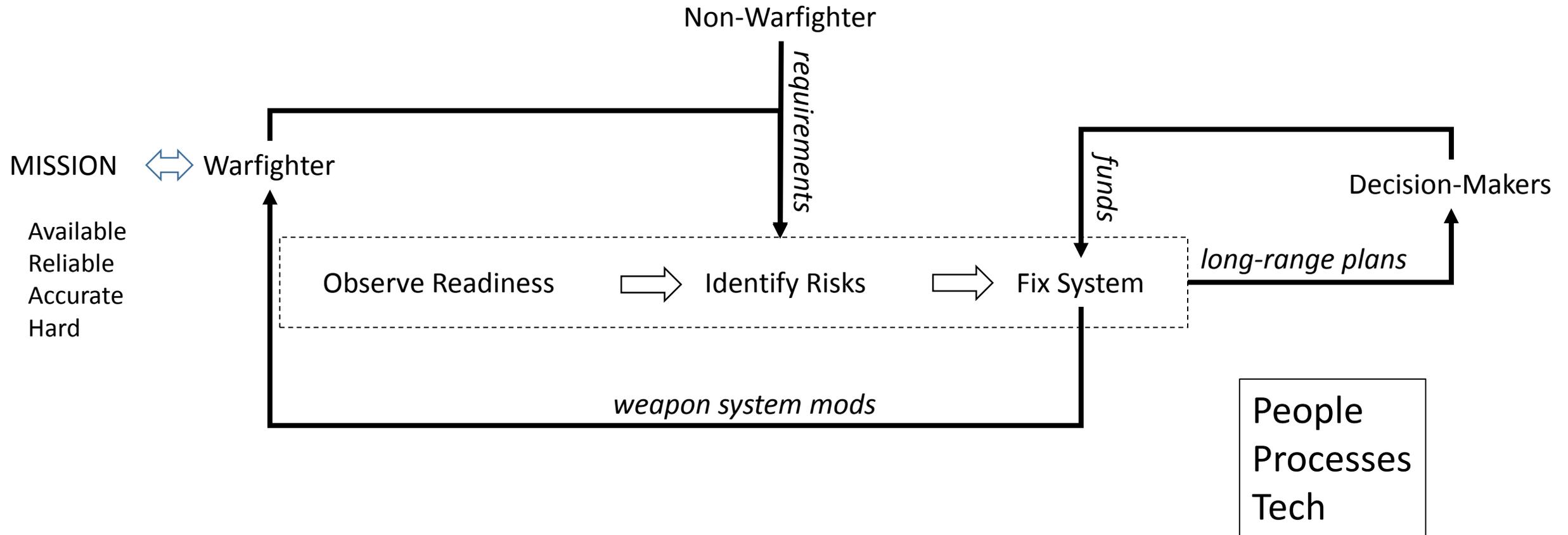
Long-lived Complex Systems

- People, not machines, realize they have specific missions
 - People, not machines, dream up systems to support the mission
 - Once the best solution is built, another mission takes our attention
-
- Realized systems strive to match the mission

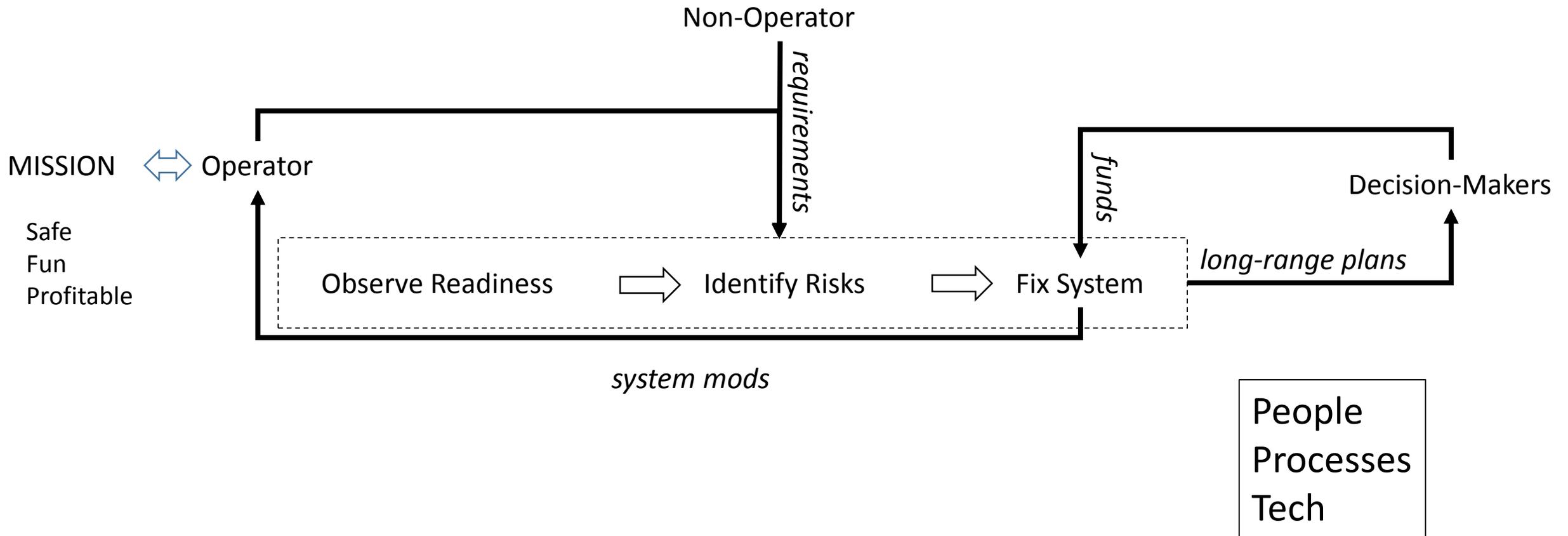
Realized Systems Strive to Match the Mission



Weapon System Sustainment Management Model



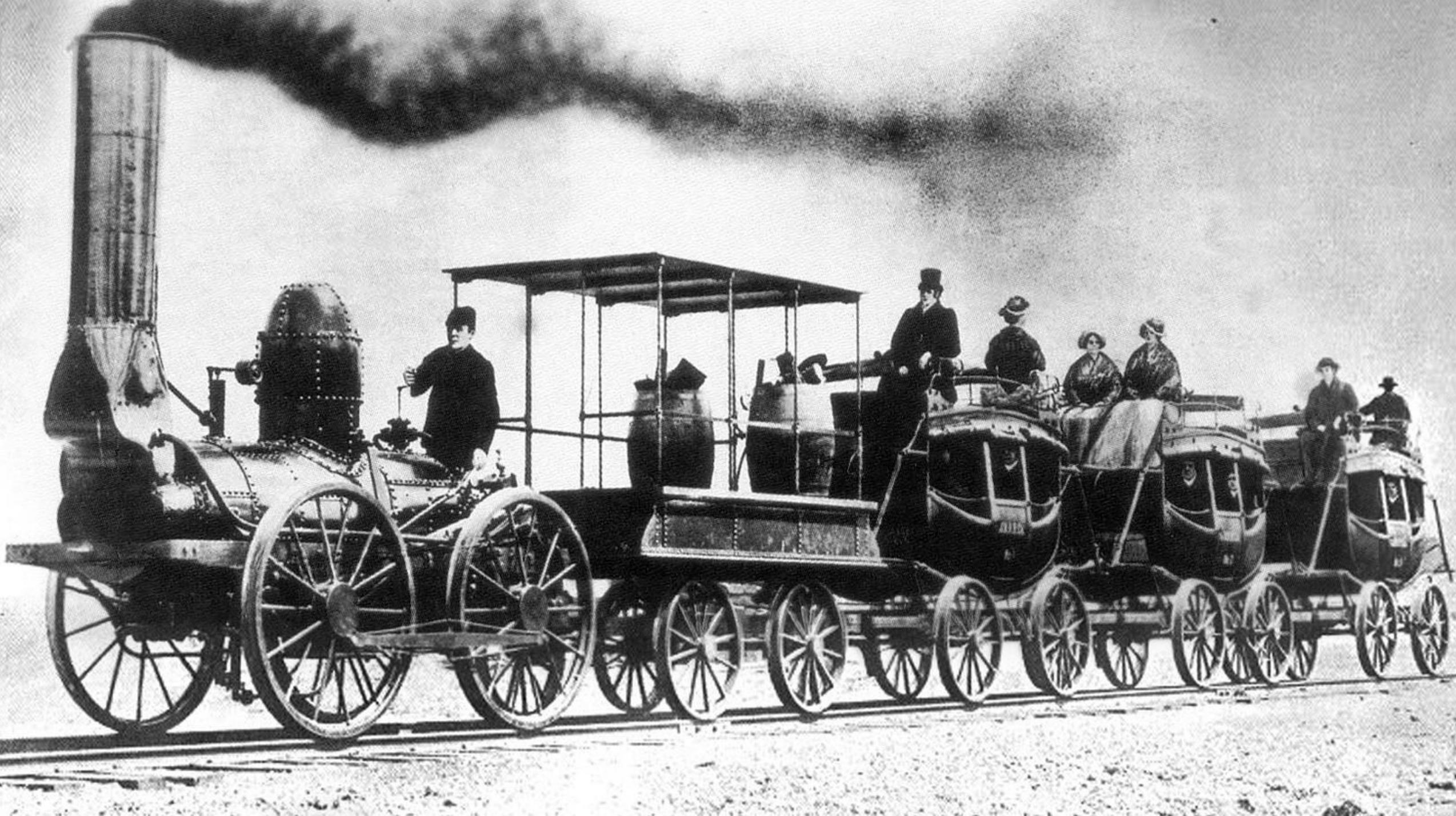
Complex System Sustainment Management Model



Further Reading

- A History of Engineering and Science in the Bell System
 - National Service in War and Peace (1925 – 1975)
 - Written by members of the technical staff, M.D. Fagen, Editor
- “Lessons Learned from Implementing Risk Management for a Legacy System”
 - Rakesh Dewan (USAF) and David Lindblad (TRW)
 - RISK Management 2000: Lessons for the Millennium Proceedings
 - The Aerospace Corporation, McLean, Virginia. November 28-December 1, 2000.
 - This paper can be found at the Defense University web site: acc.dau.mil.
- “First Steps in Implementing Weapon System Sustainment Model”
 - Charles Vono (retired)
 - AIAA SciTech 2017
- “Application of a Weapon System Sustainment Model to the Space Industry”
 - Charles Vono (retired) and Justin Kugler (Made in Space)
 - AIAA SPACE 2016
- “Fundamentals of Weapon System Sustainment”
 - Charles Vono (retired)
 - AIAA SciTech 2016
- MIT “Center for Bits and Atoms” <http://cba.mit.edu>





Back up Charts

General Curtis LeMay & Strategic Bombardment

- LeMay: The Life and Wars of General Curtis LeMay by Warren Kozak
- When the US entered WWII, LeMay was a major in the United States Army Air Forces and the commander of a newly created B-17 Flying Fortress Group. He took this unit to England in October 1942 as part of the Eighth Air Force.
- Upon arrival, the outgoing commander told him to give up. The post WWI aviation Army's dream of strategic bombardment -- crossing the fortified front lines and dealing destruction to the enemy from behind -- was impossible.
- He explained to LeMay, if you fly straight and level to drop your bombs precisely, the enemy will get you with their anti-aircraft weapons. If you don't fly straight, you will miss your target, wasting the sortie.
- LeMay considered this. After work each night for several nights, he ran the calculations. How many lives would be lost? How many aircraft would be lost if he kept to new Army Air Forces doctrine? He decided the numbers were acceptable.
- The next day, he rallied his group and told them how they would bring destruction onto Hitler's 3rd Reich. His hope was to hit hard and often to bring the terrible destruction of WWII to a quick end. Straight and level.
- His men had faith in their leader and followed him into Hell. Yes. He flew with them.
- "I have neither the time nor the inclination to differentiate between the incompetent and the merely unfortunate"

Other notable modern wars

- Spanish-American War (1898): America's new steel navy
- Second Boer War (1899-1902): Britain's machine guns could be effective, but generals did not appreciate what would happen in WWI
- WWI (1914-1918): Trench warfare and killing on an industrial scale, aircraft
- Spanish Civil War (1936 – 1939) Germany's Condor Legion aircraft bombardment at Guernica 1937
- WWII (1939-1945): Perfected aerial bombardment, created atomic weapons and long-range rockets
- Cold War (1947-1991): Rise of the Machines, nuclear weapons can strike half a world away.

USC's Sys. Mgmt. MS degree (1963-1987)

- 1952: USC created the Institute of Safety and Systems Management
 - USAF wanted to improve safety practices
 - More scientific approach and a *systems* approach
 - For aviation and other *complex* weapon systems
- 1963: MS in Aerospace Operations Management introduced
 - 1970: Curriculum expanded
 - Need for systems management of increasingly complex systems