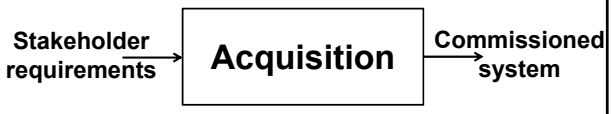
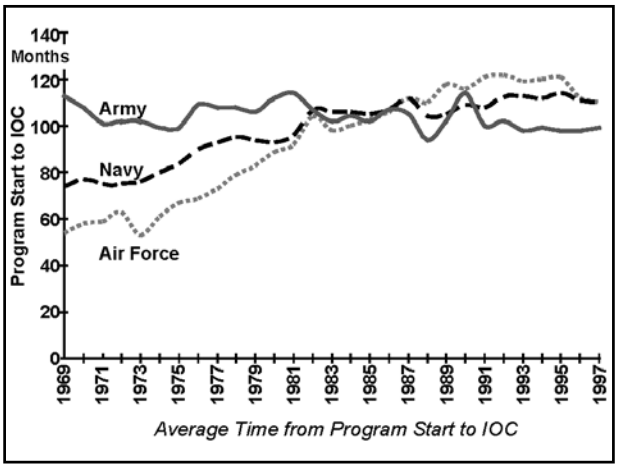
Shall we spiral?

Ad Sparrius
18 June 2013





For unprecedented systems, IKIWISI rules!

“Software requirements cannot ever be stated fully in advance, not even in principle, because the user doesn’t even know them in advance, not even in principle. Why?

The development process itself changes the user’s perceptions of what is possible, increases his insights into his own environment, and indeed often changes that environment itself.

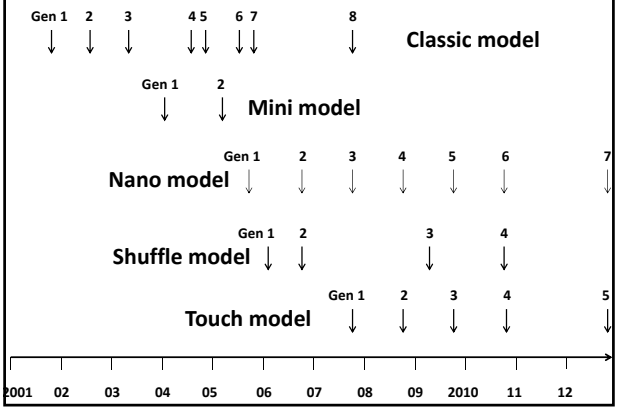
Any software development activity inevitably changes the environment out of which the need for the software originally arose. Software development should take into account that the user, his needs and his environment, all change during development.”

Jackson, McCracken; *Life cycle concept considered harmful*, ACM Software Engineering Notes, vol 7, no 2, April 1982.

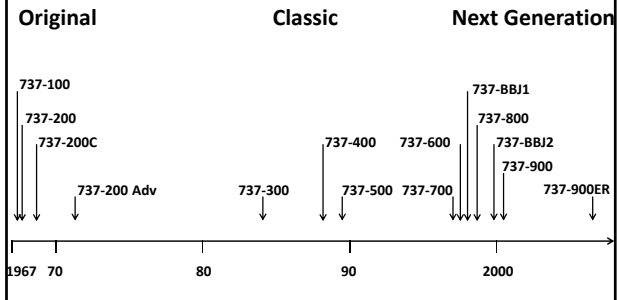
System engineering follows software engineering!

Funds will only be made available in increments

Apple iPod digital music player



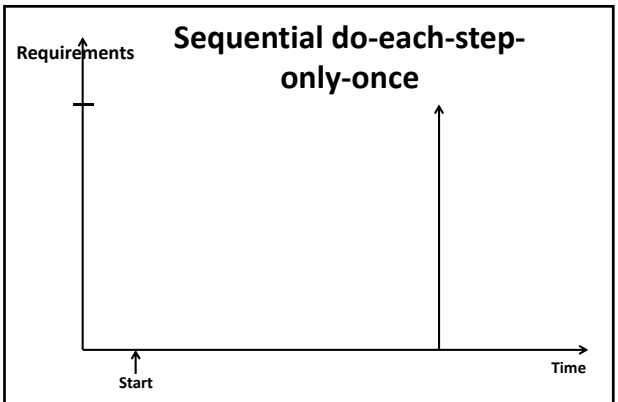
Boeing 737 short-to-medium range aircraft

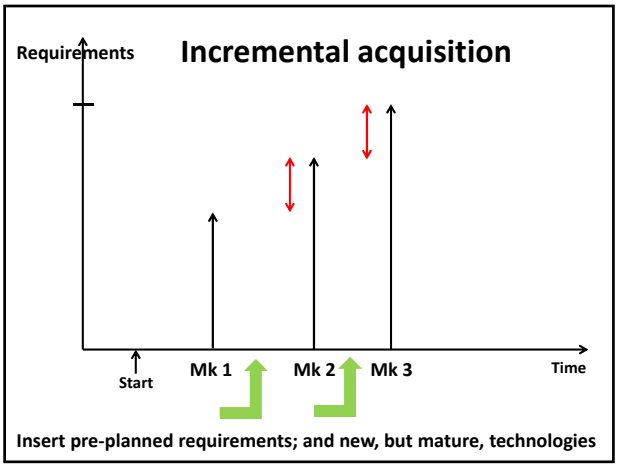


A system that is successfully used is a living, dynamic thing that continuously evolves. If it does not evolve, it is not successful.

The development of a successful system does not end when it has first been commissioned, but occurs throughout the life cycle!

Why don't we perform acquisition using these same ideas?

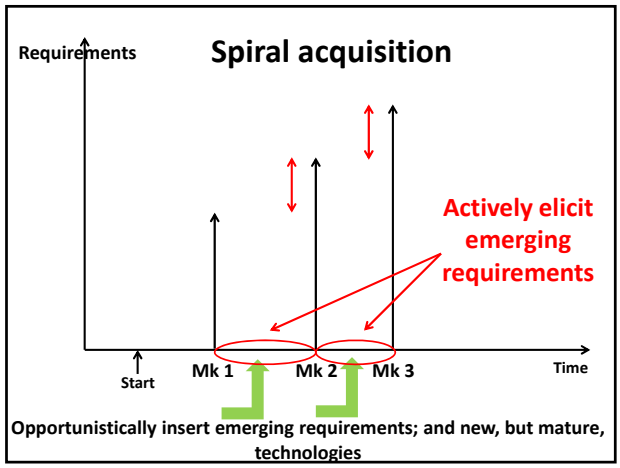




Incremental acquisition

- End-state requirements are known.
- "Defined and deferred": Work is deliberately postponed to a later version.
- Pre-planned insertions: New versions are based on new, but mature, technologies.

- An early commissioning of partial functionality is always better than waiting for full functionality.
- Divide the requirements; not the system. The system architecture should not change!

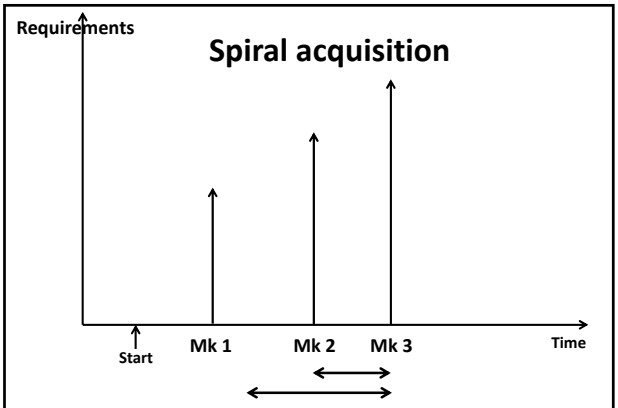


Spiral acquisition

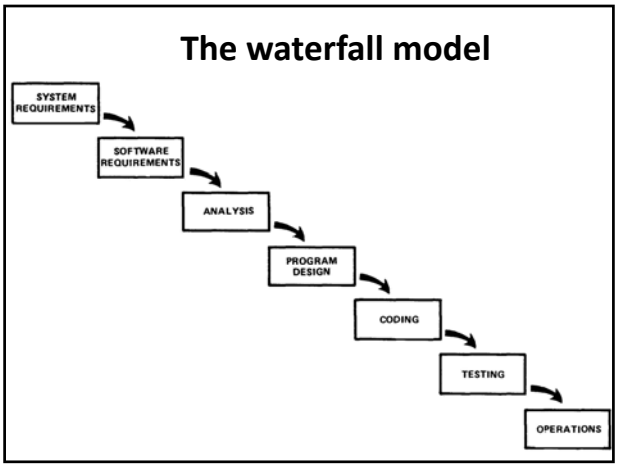
- End-state requirements are not knowable and are thus not known.
- Actively elicit user feedback to define new emerging requirements. Follow the market.
- Amorphous and opportunistic.

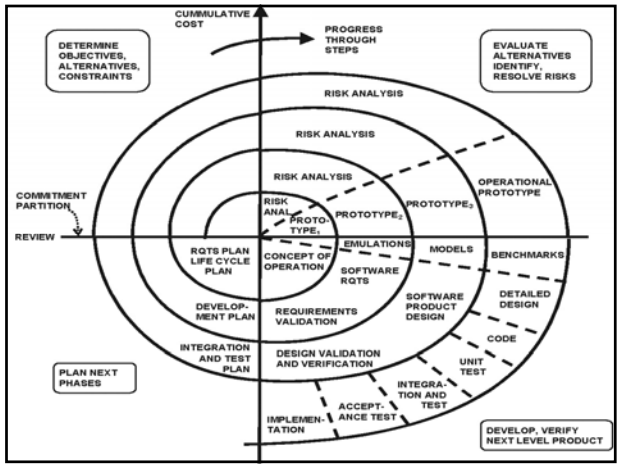
- Go as you can pay.
- New versions are based on new, but mature, technologies.

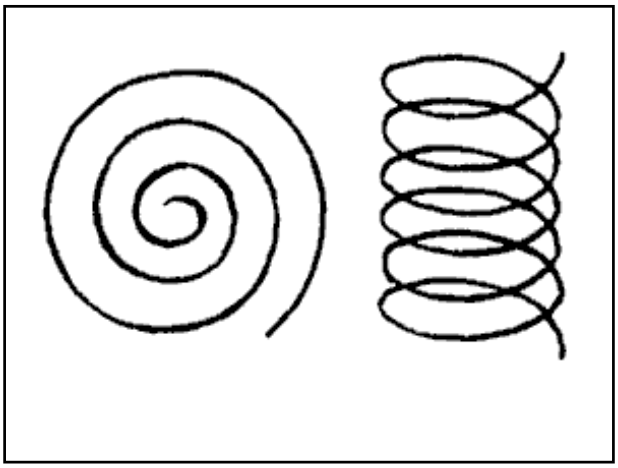
	Do-each-step-only-once	Incremental acquisition	Spiral acquisition
Define all requirements up front?	Yes	Yes	No
Multiple acquisition cycles?	No	Yes	Yes
Full requirements satisfied by first version?	Yes	No	No
User feedback to define next version's requirements?	Not applicable	No	Yes

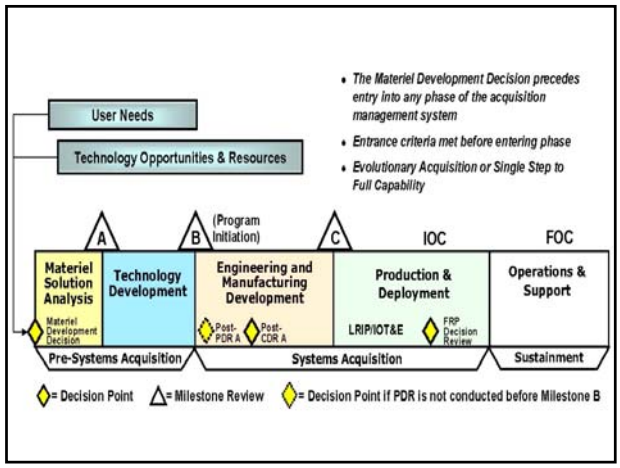


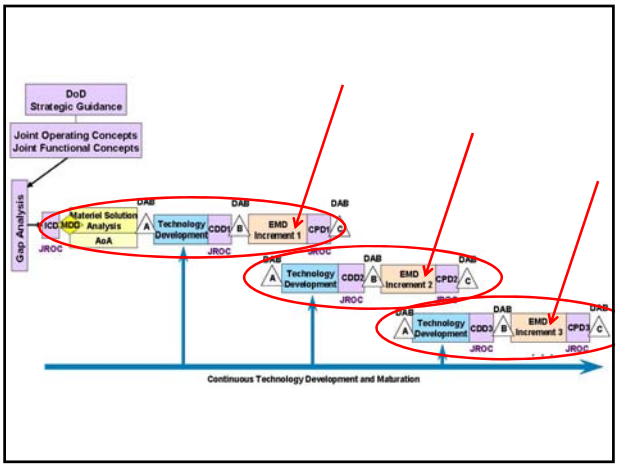
The development lead time can be much longer than the duration between versions


The waterfall model
SYSTEM REQUIREMENTS
SOFTWARE REQUIREMENTS
ANALYSIS
PROGRAM DESIGN
CODING
TESTING
OPERATIONS


CUMMULATIVE COST
PROGRESS THROUGH STEPS
DETERMINE OBJECTIVES, ALTERNATIVES, CONSTRAINTS
EVALUATE ALTERNATIVES IDENTIFY, RESOLVE RISKS
RISK ANALYSIS
COMMITMENT PARTITION
REVIEW
PROTOTYPE
OPERATIONAL PROTOTYPE
EMULATIONS
MODELS
BENCHMARKS
RQTS PLAN LIFE CYCLE PLAN
CONCEPT OF OPERATION
SOFTWARE RQTS
DEVELOP-MENT PLAN
REQUIREMENTS VALIDATION
SOFTWARE PRODUCT DESIGN
DETAILED DESIGN
CODE
INTEGRATION AND TEST PLAN
DESIGN VALIDATION AND VERIFICATION
UNIT TEST
INTEGRA-TION AND TEST
ACCEPT-ANCE TEST
IMPLEMEN-TATION
PLAN NEXT PHASES
DEVELOP, VERIFY NEXT LEVEL PRODUCT




User Needs
Technology Opportunities & Resources
• The Materiel Development Decision precedes entry into any phase of the acquisition management system
• Entrance criteria met before entering phase
• Evolutionary Acquisition or Single Step to Full Capability
A
B
(Program Initiation)
C
IOC
FOC
Materiel Solution Analysis
Technology Development
Engineering and Manufacturing Development
Production & Deployment
Operations & Support
Materiel Development Decision
Post-PDR A
Post-CDR A
LRIP/IOT&E
FRP Decision Review
Pre-Systems Acquisition
Systems Acquisition
Sustainment
= Decision Point
= Milestone Review
= Decision Point if PDR is not conducted before Milestone B



DOD Directive 5000.01,

20 November 2007.

There is no one best way to structure an acquisition program to accomplish its objectives.

Advanced technology shall be integrated into producible systems and deployed in the shortest time practical.

Approved, time-phased capability needs matched with available technology and resources enable evolutionary acquisition strategies.

Evolutionary acquisition strategies are the preferred approach to satisfying operational needs.

~~Spiral~~ Incremental development is the preferred process for executing such strategies.

ISO 15288 (2008); *Systems and Software Engineering—System Life Cycle Processes*

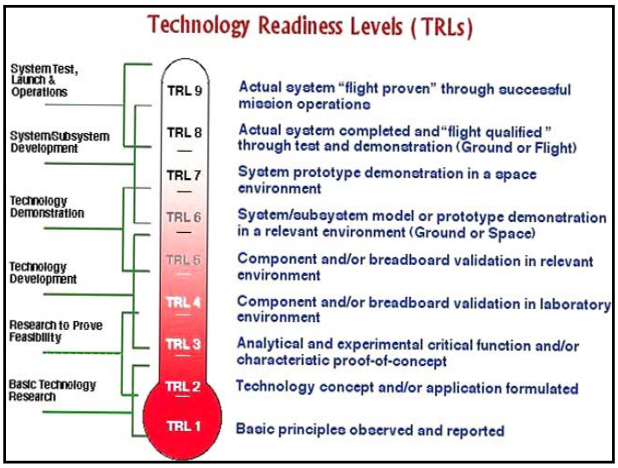
Life cycle:
Evolution of a system from conception through retirement

In traditional project management, the work scope is fixed, and determines duration and cost.
In timeboxing, the duration is fixed, and determines work scope and cost.
Typical timebox duration: 30—90 days
Timebox, don't scopebox!

Examples

- Intel's three team approach
- "No project cycle shall exceed 2% of the total project duration without delivering practical measurable benefit to the customer."

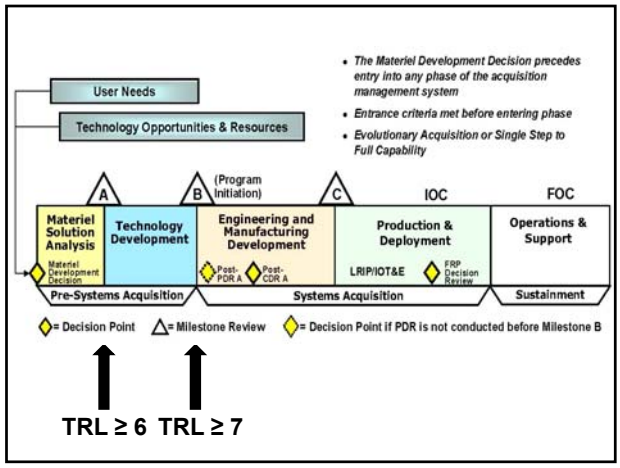
Immature technology is a key driver of cost and schedule growth



Technology Readiness Levels

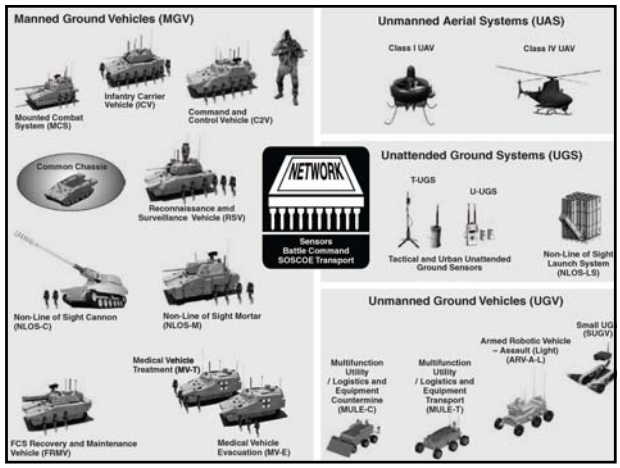
…	
5. Component and/or breadboard validation in relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.
6. System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in simulated operational environment.
7. System prototype demonstration in an operational environment.	Prototype near, or at, planned operational system. Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in an operational environment such as an aircraft, vehicle, or space. Examples include testing the prototype in a test bed aircraft.
…	

ISO 16290 (2014); *Definition of the Technology Readiness Levels (TRLs) and their Criteria of Assessment*



The US Army's Future Combat System

Replace mass with superior information based on the quality of firsts—see first, understand first, act first and finish decisively.



	TRL ≤ 5	TRL = 6	TRL ≥ 7	Total critical technologies
Actual achievement				
Project start (May 2003)	42	10	0	52
August 2006	11	34	1	46
July 2007	12	30	2	44
January 2009	4	37	3	44
Predicted achievement				
Start of develop-ment (2009)	1	40	3	44
Critical design review (2011)	0	38	6	44
Start of production (2013)	0	0	44	44

The idea of evolutionary acquisition is to use mature technology!

Postpone immature technology to a later version, and include a technology maturation plan.

Implications of evolutionary acquisition

1 Architecture first!

The *architecture* of a system are the fundamental concepts or properties of a system in its environment embodied in its elements, relationships, and in the principles of its design and evolution.

ISO 42010 (2011); *Systems and Software Engineering—Architecture Descriptions*

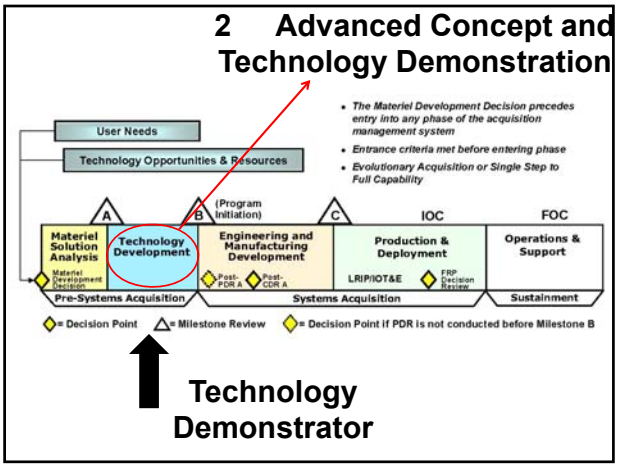
“Seven thousand years of human history would suggest the only known strategy for addressing complexity and change is architecture:

If it gets so complex you can’t remember how it works, then you have to write it down; in other words define the architecture.

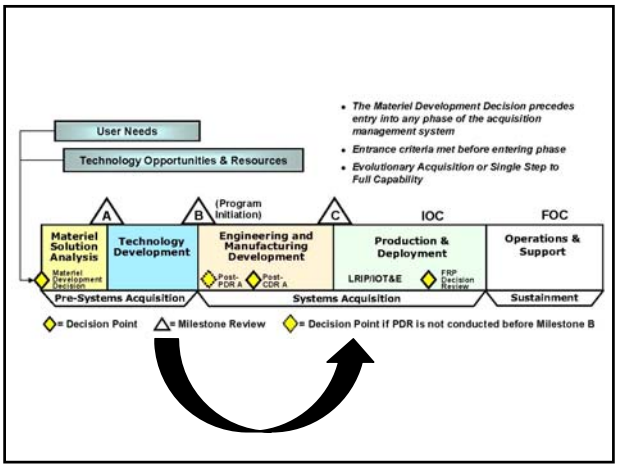
If you want to change how it works, then you start with what you have written down; in other words study the architecture.

The key to complexity and change always lies in architecture.”

John Zachman



If the technology demonstrator performs well and has the correct scale; why not start production?



Produce Mk1 in small quantities to merely satisfy immediate operational requirements. Use the time it buys to develop Mk 2.

MQ-1 Predator

- **1993 Technology demonstrator: What is the military usefulness of an unmanned aerial vehicle with a range of 1000 km and a loiter time of 24 hours?**
- **No stealth, poor survivability: expendable vehicle, ie cost USDm 5 or less.**

- **A Predator system consists of four vehicles with sensors, a ground control station, a satellite communication suite, and 55 people. Predator is not autono-mous.**

- **Very successful: Bosnia 1995, Iraq, Afghanistan, Yemen.**
- **July 2005 through June 2006: 2073 sorties and 33 833 fh.**
- **A Technology Demonstrator placed straight into production!**

- **Reduce the sensor-to-shooter delay: Change operating concept from intelligence, surveillance and reconnaissance, to also include strike.**

- **The Predator B (MQ-9 Reaper) uses a small turboprop engine that replaces the modified snowmobile engine of the Predator A.**

MQ-9 Reaper

3 Test and evaluation has to occur throughout the system's life cycle.

4 Stringent configuration management is needed to prevent requirement creep.

5 Procurement:

- How do you contract if the objectives are loosely defined?
- How do you budget for evolutionary acquisition?

6 Project management is undoubtedly more complex.

7 In difficult times, budget will be cut since the next version can easily be postponed. Less flexible acquisition projects will benefit.

8 A great deal of pressure is put on project managers to maximize the capability of the initial version, thus pushing that first version increasingly toward a traditional do-each-step-only-once acquisition.