Software development in HEP: a critical look

Federico Carminati
CERN – Geneva
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  - They invented them!
- The programs of the LHC era are of unprecedented complexity
  - Measured in units of 10^6 lines of code (MLOC)
  - Communities are very large (ATLAS > 2000 physicists and engineers)
- Failure to develop appropriate programs would jeopardise the extraction of the physics from the data
- … i.e. it would ultimately waste multi-million dollars investments in hardware and thousands of man years of highly qualified efforts

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  - ~10 instructions!
  - The standard is 50 pages
- In the LHC era the code is written in many cooperating languages, the main one is C++
  - O(100) instructions
  - “Nobody understands C++ completely” (B.Stroustrup)
  - The standard is 700 pages
- Several new languages have been emerging with an uncertain future
  - C#, Java, Perl, Python, php…
- The Web world adds a new dimension to computing
- Not to talk about GRID…

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- Physicists are both developers and users
- The community is very heterogeneous
  - From very expert analysts to occasional programmers
  - From 5% to 100% of time devoted to computing
- The community is very sparse
  - The communication problem is serious when developing large integrated systems
- People come and go with a very high rate
  - Programs have to be maintained by people who did not develop them
  - Young physicists need to acquire knowledge that they can use in their careers (also outside physics)
- The physicists have no strict hierarchical structure in an experiment

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- In this complex and high-risk environment it seems natural to ask for help to those who make a living solving similar problems
- This is where the physicist meets the computer scientist
- But the interaction has been far from a honeymoon…
- … and the neighbour’s grass just looked greener

HEP & SE

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  - H.D. Benington, "Production of Large Computer Programs", Proceedings, ONR Symposium, June 1956
  - F.L. Bauer, 1968, NATO conference

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Software, software crisis and SE

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- Major worry of managers is not
  - Will the software work?
- But rather
  - Will the development finish within time and budget?
  - … or rather within which time and budget …
- SE has been proposed to solve the Software Crisis
  - More a goal than a definition!
  - A wild assumption on how engineers work
  - Can’t build it like a bridge if it ain’t a bridge

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  - Classic example is the OS/360 operating system. 10 years and 1000 programmers. F.Brooks claims in Mythical Man Month that he made a multi-million dollar mistake by not developing a coherent architecture before starting
- Property Damage
  - Identity stealing from hackers costs time, money, and reputations
- Life and Death
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  - Structured programming, object-oriented programming, CASE tools, Ada, Java, documentation, standards, and Unified Modeling Language were touted as silver bullets
- Discipline
  - The software crisis was due to the lack of discipline of programmers
- Formal methods
  - Apply formal engineering methodologies to software development, to make production of software as predictable as other branches of engineering, proving all programs correct
- Process
  - Processes and methodologies like the Capability Maturity Model
- Professionalism
  - This led to work on a code of ethics, licenses, and professionalism

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- Only very slowly women are finding back their place in programming

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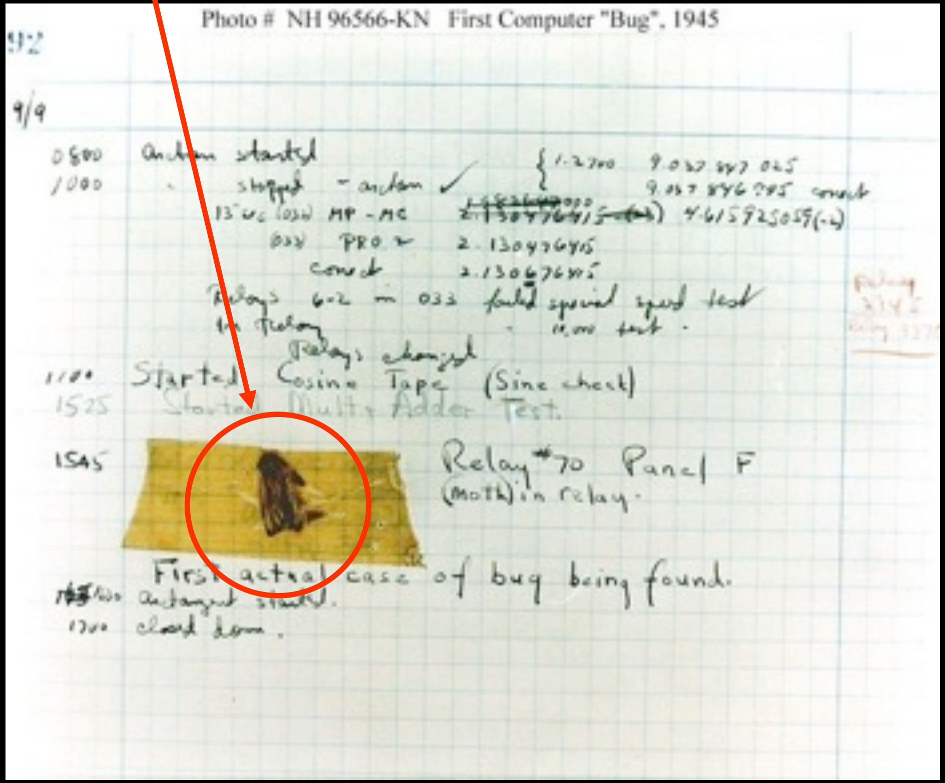

Photo # NH 96566-KN First Computer "Bug", 1945

92

9/9

0800 Anctan started
1000 " stopped - anctan ✓ {1.2700 9.037 847 025
9.037 846 995 correct
13" UC (032) MP - MC ~~1.982147000~~ ~~2.130476415~~ 4.615925059(-2)
(033) PRO 2 2.130476415
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Relays 6-2 in 033 failed special speed test
In relay " 10.000 test.
Relays changed
1100 Started Cosine Tape (Sine check)
1525 Started Mult + Adder Test.
1545 Relay #70 Panel F
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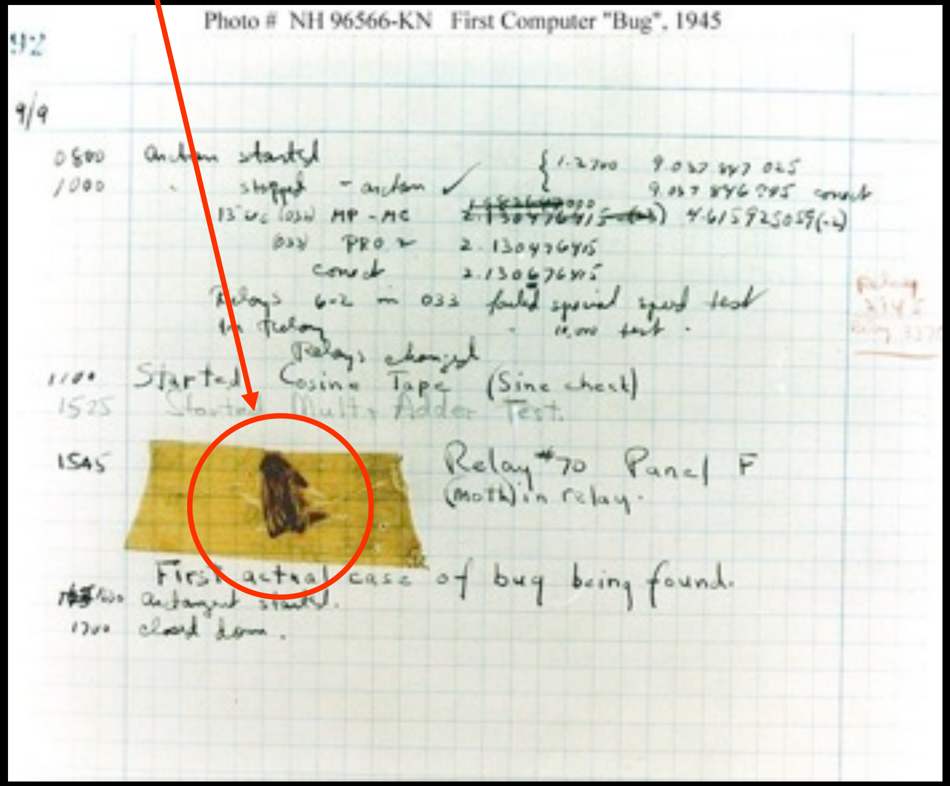

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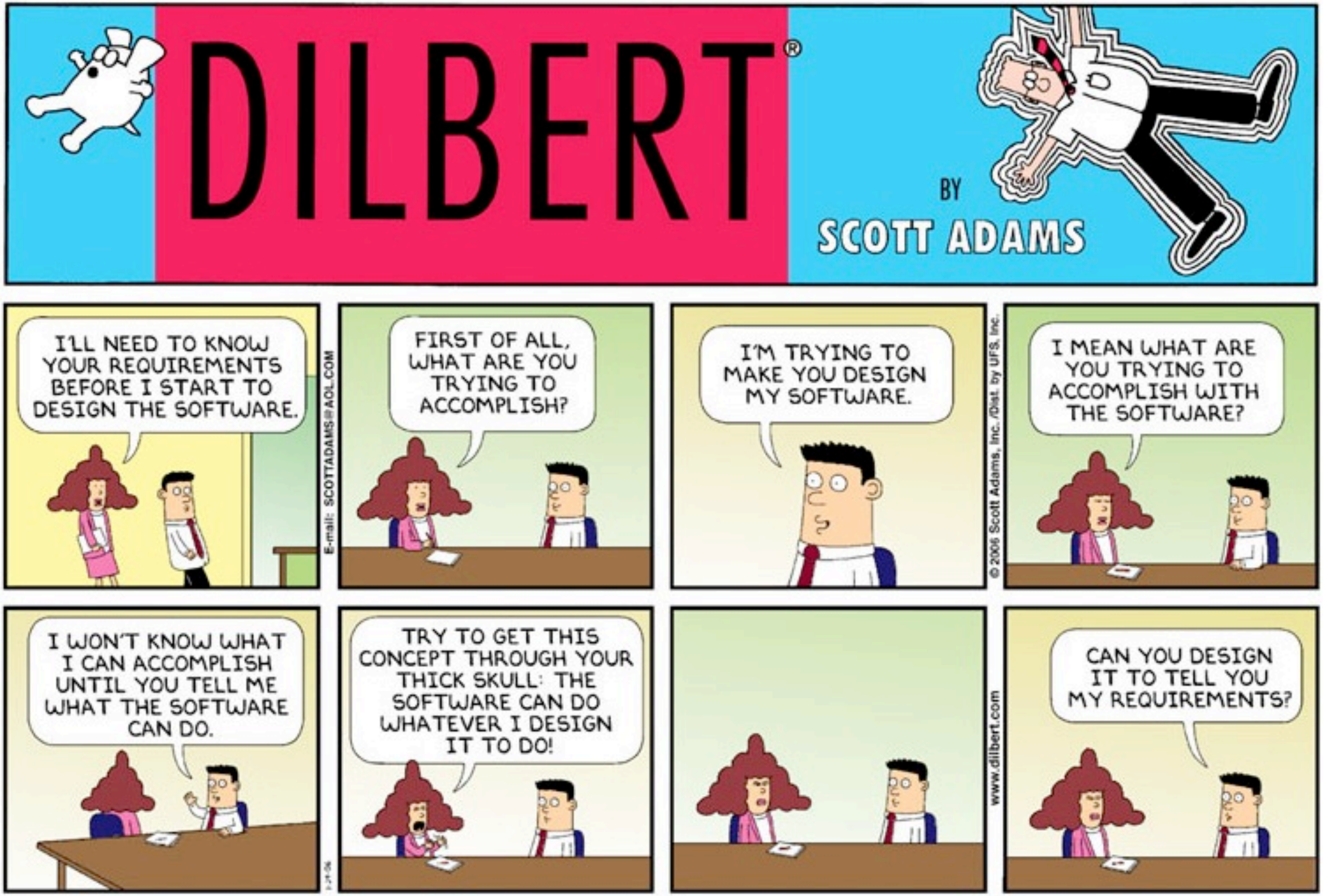
DILBERT®
BY SCOTT ADAMS
I'LL NEED TO KNOW YOUR REQUIREMENTS BEFORE I START TO DESIGN THE SOFTWARE.
E-mail: SCOTTADAMS@AOL.COM
FIRST OF ALL, WHAT ARE YOU TRYING TO ACCOMPLISH?
I'M TRYING TO MAKE YOU DESIGN MY SOFTWARE.
© 2006 Scott Adams, Inc. /Dist. by UFS, Inc.
I MEAN WHAT ARE YOU TRYING TO ACCOMPLISH WITH THE SOFTWARE?
I WON'T KNOW WHAT I CAN ACCOMPLISH UNTIL YOU TELL ME WHAT THE SOFTWARE CAN DO.
TRY TO GET THIS CONCEPT THROUGH YOUR THICK SKULL: THE SOFTWARE CAN DO WHATEVER I DESIGN IT TO DO!
www.dilbert.com
CAN YOU DESIGN IT TO TELL YOU MY REQUIREMENTS?

- Software is opposed to hardware because it should be flexible
- Yet the reason of the failure of software process is often identified in the changes intervening during the development
- The heart of SE is the limitation of the impact of changes
  - Changes are avoided by a better design
  - A better design is obtained by exhaustive requirements
  - The more complete the design, the less the changes, the smaller the cost of software

SE crisis

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- SE splits the process in a sequence of controllable phases
  - Analysis, design, implementation, testing, maintenance…
  - A hierarchy and a roadmap to navigate among them
- Still software projects continue to fail: the SE crisis
- Orthodox SE diagnosis is: not enough SE was applied
  - More discipline and more strict observance of the rules
  - Too process kill the process, projects keeps failing
- Modern SE tries to find a different answer

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- Many formal paper documents
- Very detailed design models, difficult to read and understand
- Formal document ownership
- Distinct developer roles
- Communications through documents
- Formal process to follow
- HCP are suited for big projects, with stable requirements
  - The time elapsed from requirement gathering to start coding may be as long as 1-2 years
- In the e-business era (and in science!) projects are characterized by
  - High speed, change and uncertainty

High Ceremony Process

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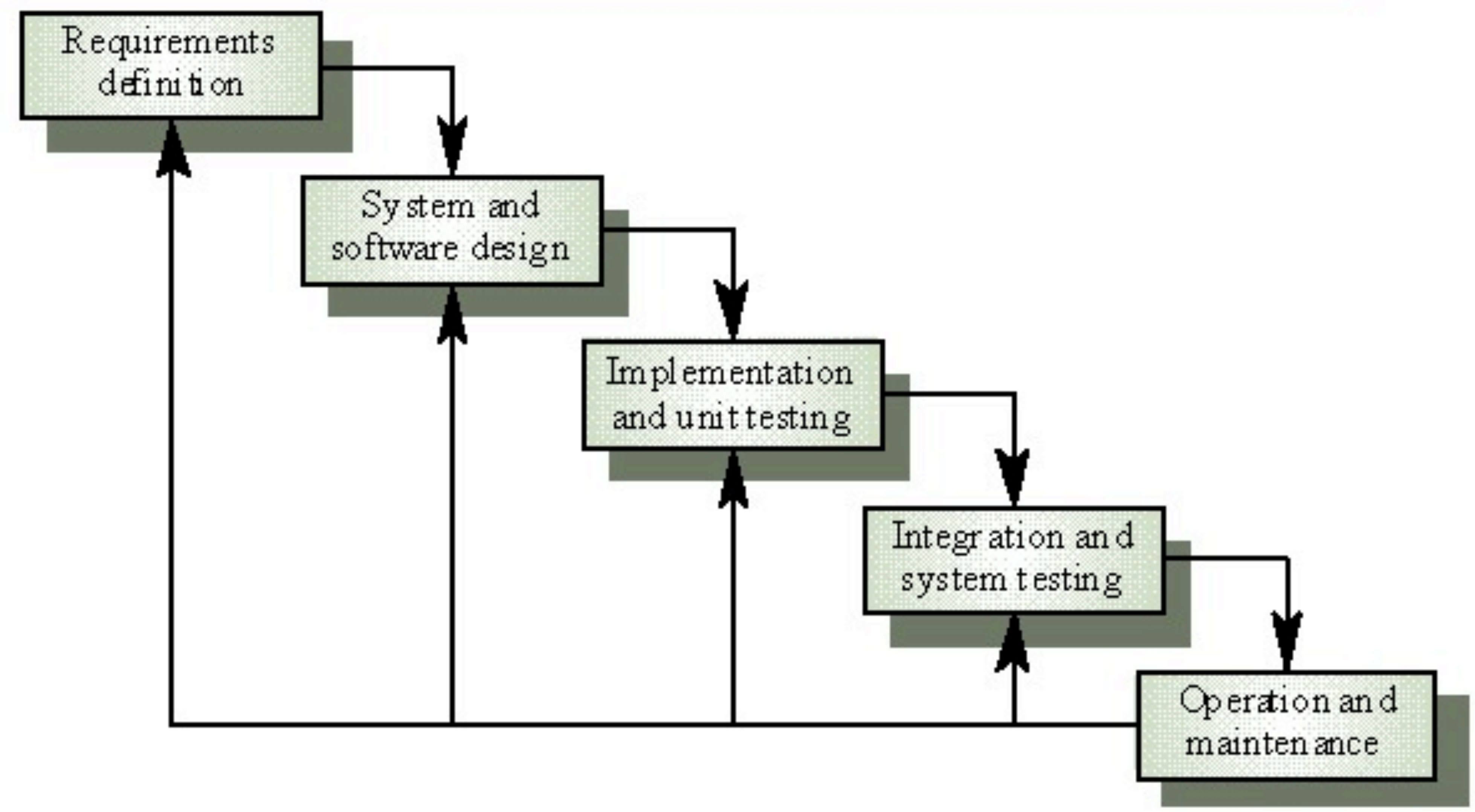
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System and software design
Implementation and unit testing
Integration and system testing
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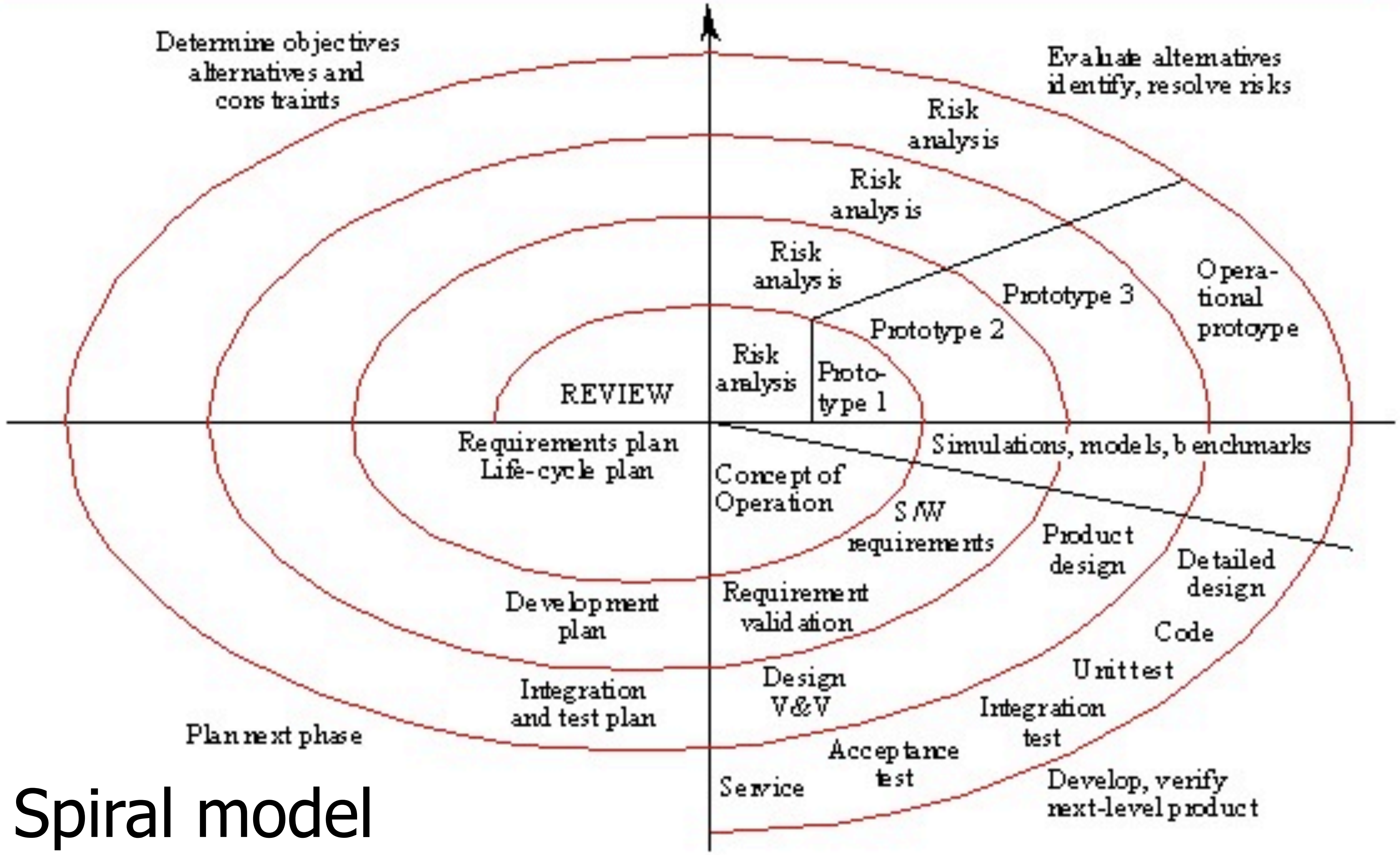

Spiral model

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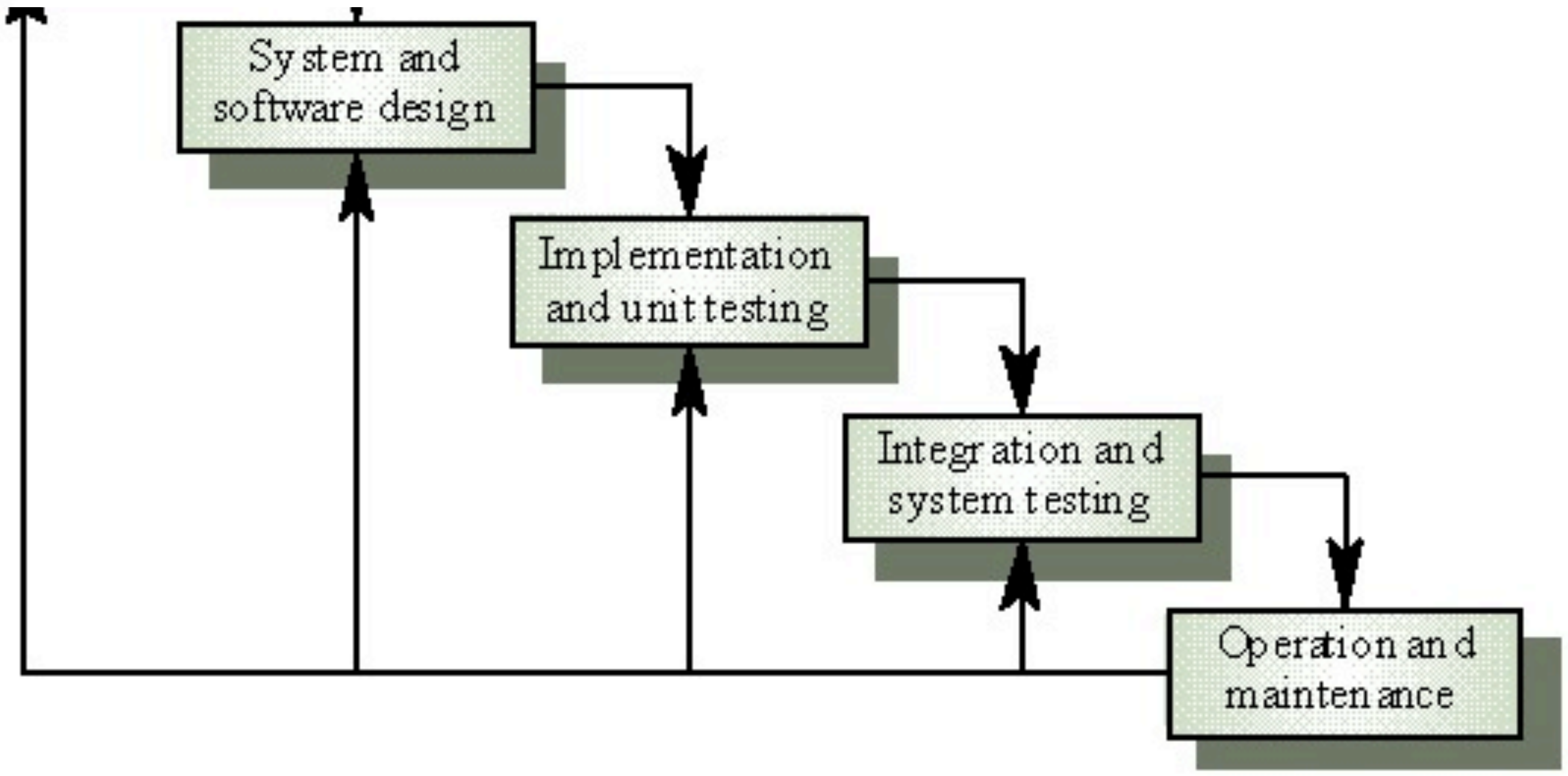
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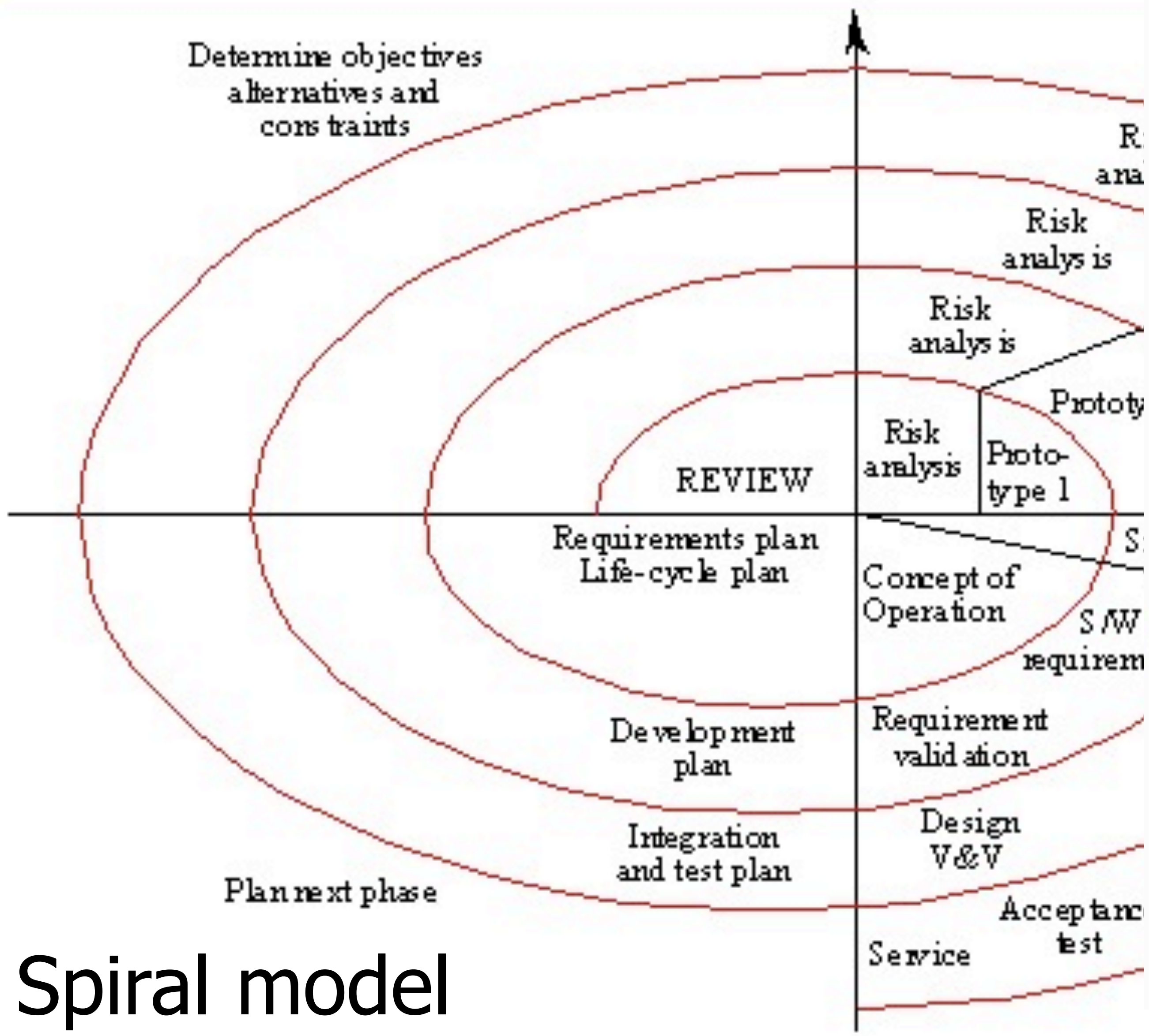

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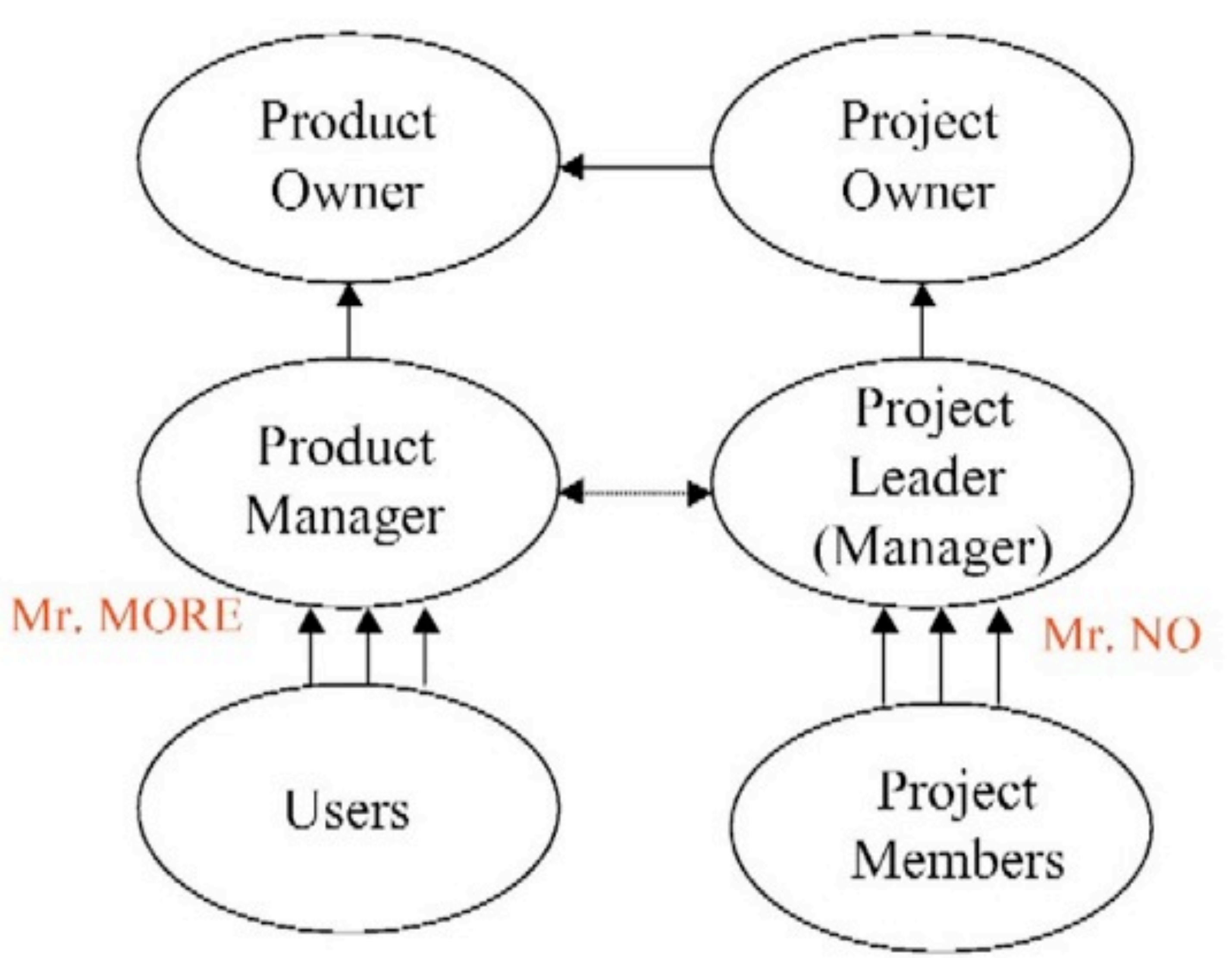

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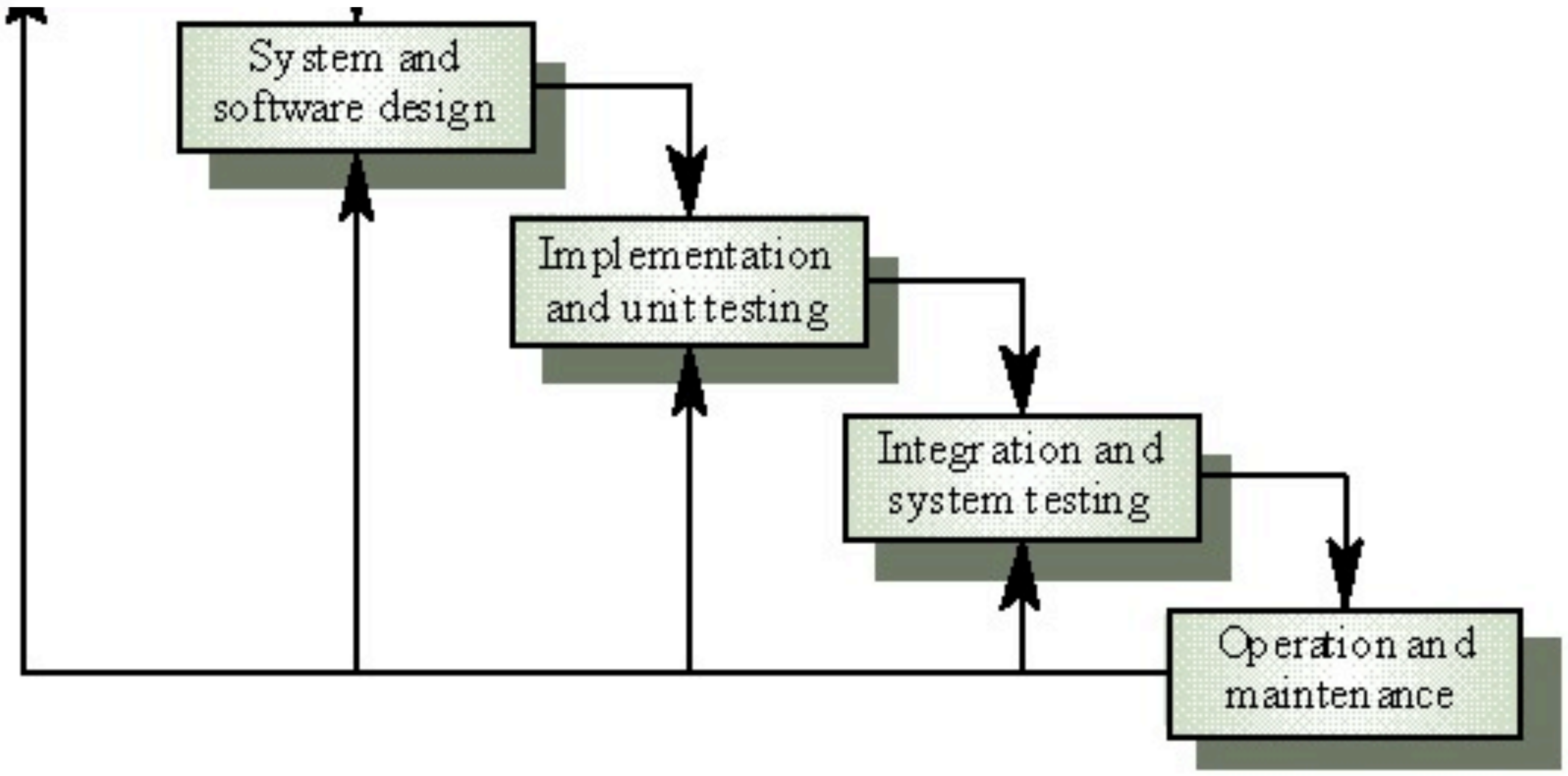

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- From mid 80's to mid 90's SE has been looking for the silver bullet
- From mid 90's onward came the realisation that developing working software was just very hard
- SE has given us a much deeper understanding of the process of software development
- But we still miss a "magic solution"

Did SE fail?

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A Software Engineer’s nightmare

- A Soft Engineer’s view of HEP
  - ✓HEP has a complicated problem to solve
  - ✓SE is good for complicated problems
  - ✓These physicists cannot even spell SE correctly
  - ✓A bit of SE can do wonder
    - Or, in its weaker form, it should work at least here!
  - ✓Let’s introduce SE in HEP!
- A scheduled success!
- What can possibly go wrong?

- HEP has tried all new SE technologies, tools and formalisms
  - Yourdon's SASD, ER, Booch's OOADA, Rambaugh's OMT, Shlaer-Mellor's OL, ESA's PSS-05, UML, USDP
  - ADAMO, I-Logix Statemate, OMW, OMTool, StP, Rational Rose, ObjecTime, Together
- All have raised interest and then fallen into oblivion
- The OO projects started in '94 have used extensively SE
  - GEANT4 was late in entering production (8 years)
  - Spider has been cancelled
  - LHC++/ANAPHE/AIDA never could replace PAW / CERNLIB and have finally been abandoned
- The winning product (root!) never claimed any use of SE
- Did traditional SE fail to deliver?

HEP software & Software Engineering

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  - This is a success that cannot be denied
- However Grid MW projects are grossly over budget, late and under expectations
- Yet they have put an enormous focus on the usage of proper (classic!) SE methods
- What went so wrong?

A case study – the Grid

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- Insistence on complete requirements
  - But users never saw a Grid before!
- Ask the same question till you get the answer you want
  - “This is not a requirement…”
- Insist on one single line of development
  - Bureaucracy before creativity
- Develop incompatible versions of the same product
  - Ping-pong support
- Multiply “testbeds” without users
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  - Experiments have not been hindered by software in their scientific goals
- CERNLIB (GEANT3, PAW, MINUIT) has been an astounding success
  - From small teams in close contact with experiments
  - In use for over 20 years
  - Ported to all architectures and OS that appeared
  - Reused by hundreds of experiments around the world
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- Did we do something right?

HEP software: the facts

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i.e. getting rid of the mantra "let's do it as they do it in industry…"

- Fuzzy & evolving requirements
  - If we knew what we are doing we would not call it research
- Bleeding edge technology
  - The boundary of what we do moves with technology
- Non-hierarchical social system
  - Roles of user, analyst, programmer etc are shared
  - Very little control on most of the (wo)man power
- Different assessment criteria
  - Performance evaluation is not based on revenues
  - We do not produce wealth, we spend it!
  - We produce knowledge, but this is not an engineering standard item

HEP Software, what's special?

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- Traditional SE does not fit our environment
  - Only applicable when requirements are well understood
  - Our non-hierarchical structure does not match it
  - We do not have the extra (wo)man power for it
  - It introduces a semantic gap between its layers and the additional work of translating, mapping and navigating between them
- It acts on the process and not on the problem
  - It structures the activity constraining it to a limited region, with precisely defined interfaces
  - A Tayloristic organization of work, scarcely effective when the product is innovation and knowledge

Is SE any good for us?

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"In my experience I often found plans useless, while planning was always invaluable."

D.Eisenhower

- Change is no accident, it is **the** element on which to plan
  - As such it must be an integral part of the software process
- Need to reconsider the economy of change
  - Initial design needs not to be complete or late changes bad
- Designing is still fundamental
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- However sticking to an out-of-date design would
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  - Limit the functionality of the code
  - Waste effort on no-longer needed features
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- Develop a (functional) prototype with the features that are felt to be more relevant by the community
  - The story becomes quickly a reality (short time-to-market)
  - Interested and motivated users use it for day-by-day work
  - Must master equilibrium between too few and too many users

How do we work?

(an idealised after-the-fact account of events)

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- Users collectively own the system and contribute to it in line with the spirit of the initial common story
  - New versions come frequently and the development one is available
- Redesigns happen, even massive, without blocking the system
- Users tend to be vocal but loyal to the system
  - It is their system and it has to work, their needs are satisfied
- Most of the communication happens via e-mail
- Relations are driven by respect and collaborative spirit
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- Modern SE tries to find short time-to-market solutions for rapidly changing
  - Requirements
  - User community
  - Hardware/OS base
  - Developer teams
- This is the norm for HEP
  - Once more we are today where IT will be tomorrow
- Modern SE seems to formalise and justify the conventions and rituals of HEP software
  - Minimise early planning, maximise feedback from users, manage change, not avoid it
- Can we gain something out of it?

Is there method to this madness?

- Modern SE tries to find short time-to-market solutions for rapidly changing
  - Requirements
  - User community
  - Hardware/OS base
  - Developer teams
- This is the norm for HEP
  - Once more we are today where IT will be tomorrow
- Modern SE seems to formalise and justify the conventions and rituals of HEP software
  - Minimise early planning, maximise feedback from users, manage change, not avoid it
- Can we gain something out of it?

- Famous article from E.Raymond on software development (1997)
  - Rapid prototyping
  - User feedback
  - Release early release often
- One of the first fundamental criticisms to the traditional software engineering

"Linux is subversive..."

The Cathedral and the Bazaar

http://www.tuxedo.org/~esr/writings/cathedral-bazaar/

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> Michelangelo

- Simplicity is the most complicated thing to achieve in software development
- Simplicity should be the objective of continual planning and refactoring
- Simplicity should be part of the initial design

Simplicity, emergence and the like

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  - Do not throw away long-term gains in order for little short-term money. Avoid pressure for cooperators to defect
- Availability of source Code
  - You can't evolve programs without modifying them
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  - For rapid evolution to happen, people need to be able to experiment with and redistribute modifications
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Open Source (more than just the code…)

"Live free or die"

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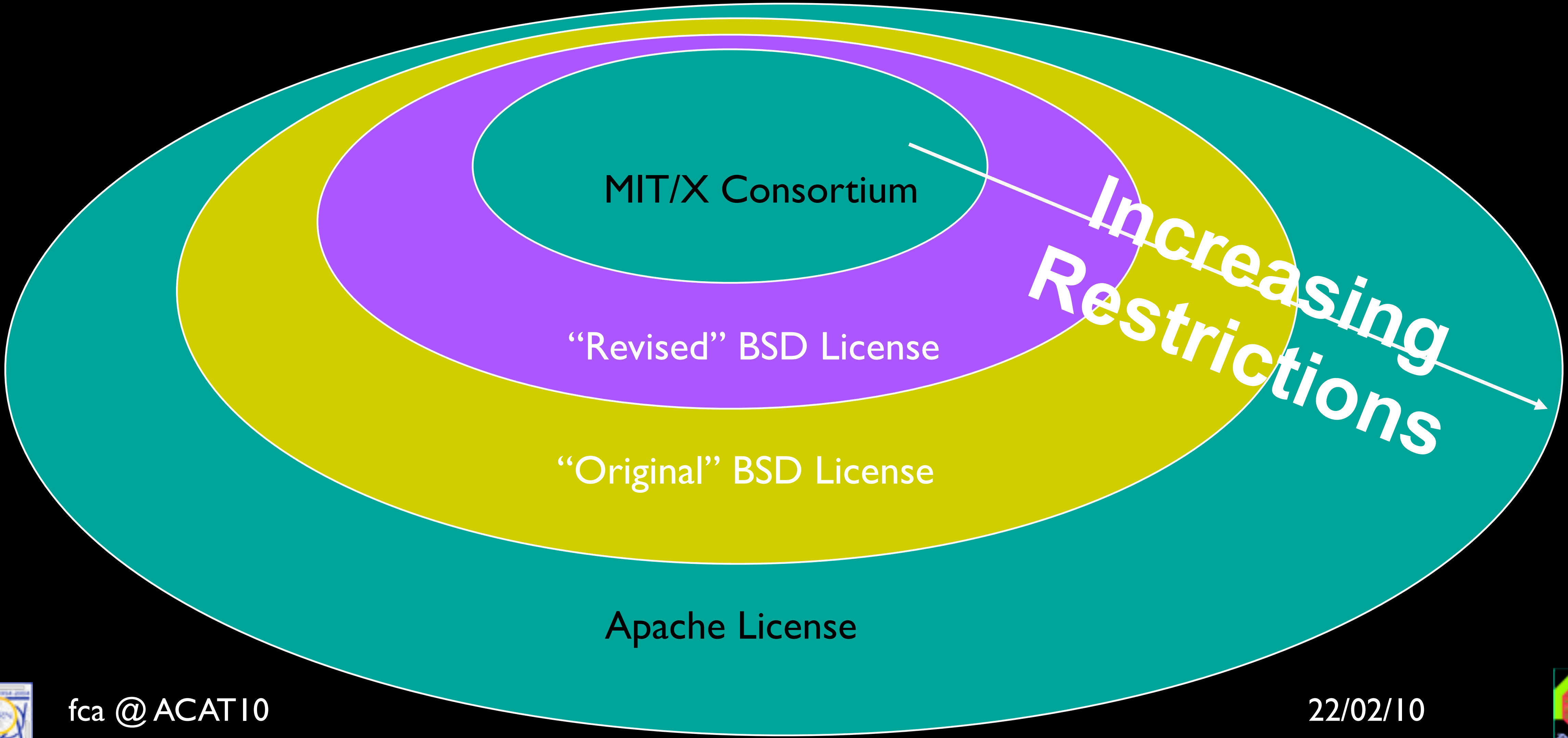

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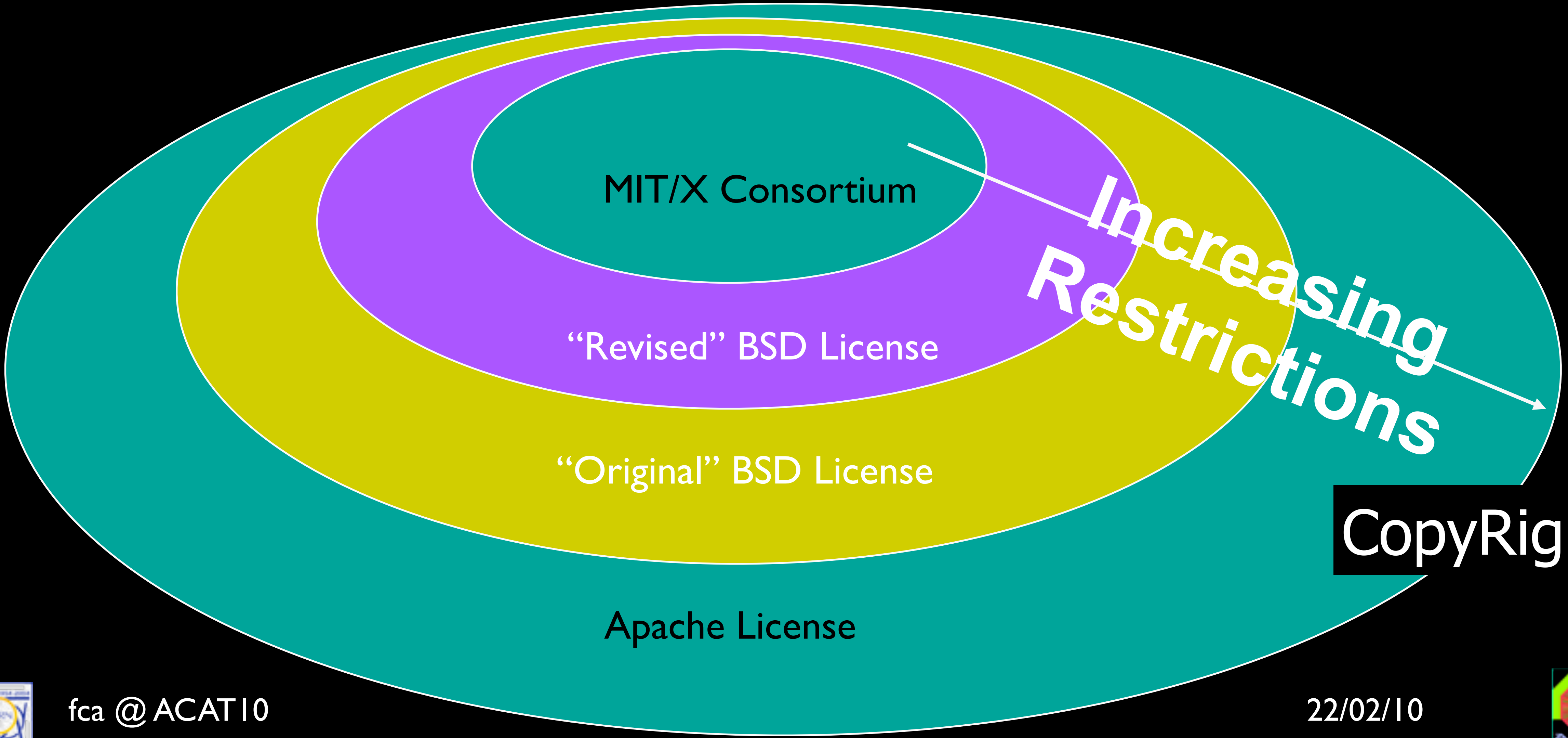

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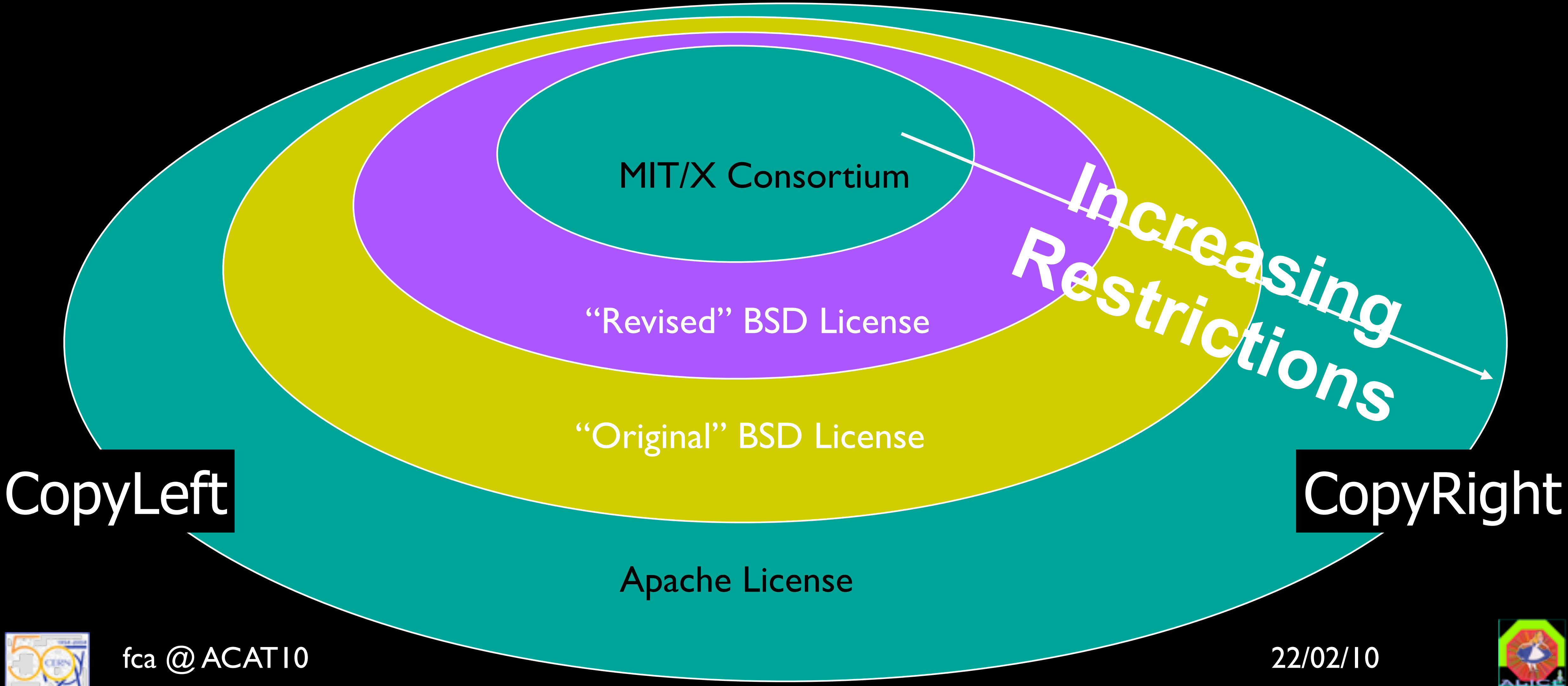

OS licenses

- The world of Open Software licenses is very complicated

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Agile Technologies
(aka SE catching up)

- SE response to HCP are the “Agile Methodologies”
  - Adaptive rather than predictive
  - People-oriented rather than process-oriented
  - As simple as possible to be able to react quickly
  - Incremental and iterative, short iterations (weeks)
  - Based on testing and coding rather than on analysis and design

- Uncovering better ways of developing software by valuing:

Individuals and interactions	**OVER**	processes and tools
Working software		huge documentation
Customer collaboration		contract negotiation
Responding to change		following a plan

That is, while there is value in the items on the right, we value the items on the left more.

- There are four factors to control a software project: time, manpower, quality and scope
- Time
  - The worst of them all… but the most widely used
- Manpower
  - The most misused … add people to a project which is late and you will make it later
- Quality
  - A parameter very difficult to control … writing bad software may take more time than writing good one
- Scope
  - The least used. It needs clear communication and courage, but is probably the most effective if well managed

Managing expectations

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  - Based on small, very interacting teams of people working in pairs
  - Testing is practiced since the very beginning
  - System integration is performed daily
  - Use cases driven, with specific techniques to estimate time and cost of the project
  - Programs are continuously refactored
  - Written documentation besides code is kept to minimum
  - Write the simplest system that can work!
- Move stability from plans to planning

eXtreme Programming

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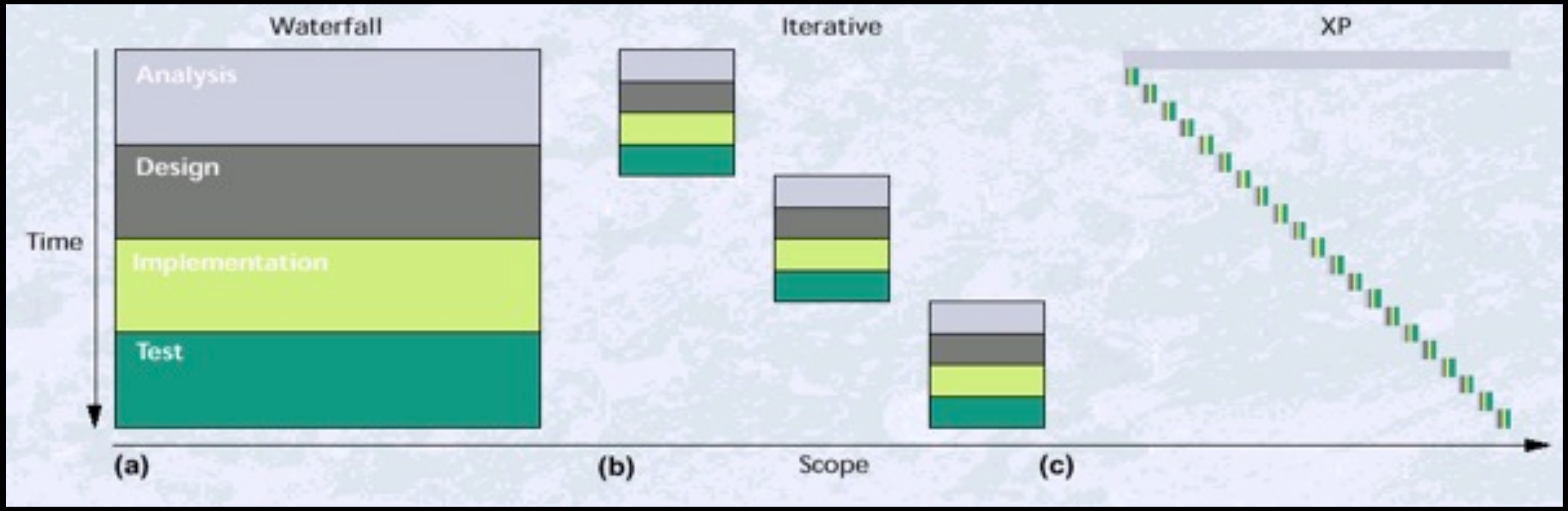

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- This movement may be important for HEP as we can finally
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(a preliminary) Conclusion

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"That's
all
folks!"