Building the Wendelstein 7-X

Antonio Gittens, MEng Candidate antonio.gittens@mail.utoronto.ca
Lavender Zhang, MEng Candidate laviez@gmail.com
Marina Freire-Gormaly, MASc marina.freire.gormaly@gmail.com

27-Sep-2014

Outline

- Background
- Why is the W7-X project interesting?
- Lessons learned
- Summary

Background

- W7-X is a stellarator-type nuclear fusion reactor
- First attempt to optimize large-scale stellarators
  - Key step in developing commercial power generators
- Located in Greifswald, Germany at the Max Planck Institute for Plasma Physics
- Launched in 1996, commissioning started in May 2014

Background

Source: http://www.hazemsakeek.net/ar/?p=5305

Key Project Challenges

- Unique toroidal shape not seen in other reactors
  - Required a new and complex design
- Novel materials and manufacturing processes
  - Suppliers had to invent much of what was needed
- High standards and tight tolerances
- Final product is an experimental research facility

Lesson 1: Schedule Planning

- *Tight Schedules Impractical with Unproven Designs*
  - Structural supports required several design changes
  - Estimates were unrealistically low
  - Little contingency was included
- Design changes are inevitable
  - Schedule must consider level of confidence in estimates

Source: http://www.iter.org/doc/www/content/com/Lists/Stories/Attachments/680/ITER_W7X.pdf

Lesson 2: Stakeholder Management

- *Involving New Stakeholders Can Bring More Resources*
  - New magnetic coils were needed but not in budget
  - U.S. research interest in stellarators was increasing
  - Offered Americans partnership in research in exchange for $9M in new coils
- Monitoring developments of neutral, low-interest, low-power stakeholders could pay off

Lesson 3: Stakeholder Management

- *Find Non-Monetary Incentives for Reluctant Stakeholders*
  - W7-X was high-risk for suppliers so costs are high
  - Suppliers needed to be EU-Approved to get other fusion contracts
  - Offered non-approved suppliers a path to approval
- Creativity can reveal a cheap way to shift engagement levels

Lesson 4: Risk Management

Sources: http://www.dw.de/babcock-files-for-insolvency-but-talks-continue/a-588129, http://www.wsws.org/en/articles/2002/07/borg-j24.html, http://news.bbc.co.uk/2/hi/business/2096953.stm

Lesson 4: Risk Management

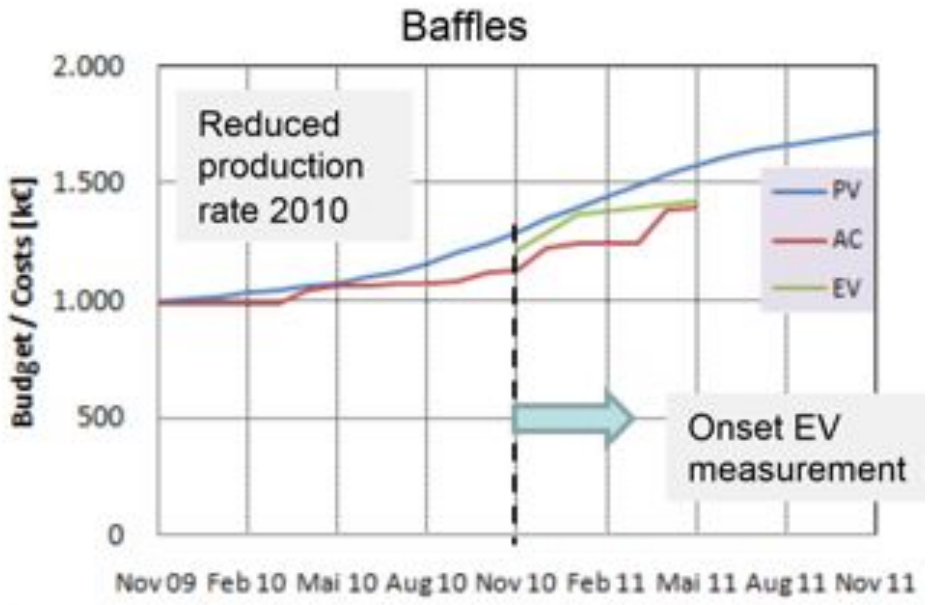
- *Incomplete Risk Assessment Could Jeopardize Schedule*
  - Babcock Borsig led consortium of coil manufacturers
  - Declared bankruptcy in 2002
  - Signs of financial difficulty well before contracts were finalized
- May be better to split contracts across firms
  - Mitigates risk but doesn't avoid it

Lesson 5: Cost Management

- ***Earned Value Management Tools Should be Used to Monitor and Control the Project***
  - W7-X adapted EVM tools to their project needs
  - A separate EVM tool for Assembly, Diagnostic Engineering and In-Vessel components

EVM for Assembly	EVM for Diagnostics	EVM for In-Vessel
Monthly	*Weekly*	*Monthly*
Tracked internal and external workforce	*Tracked progress against design hours*	*Tracked Internal and External hours*
Work Packages assigned to 'units' within the Assembly Plan	*Milestone monitoring system with monthly management meeting*	*Timescale of years (e.g. 2006-2011 for plasma facing baffles)*

Example of EVM-In Vessel



Source: http://w3.pppl.gov/~neumeyer/SOFE/Presentations/SO4/SO4C-4%20Lorenz.pdf

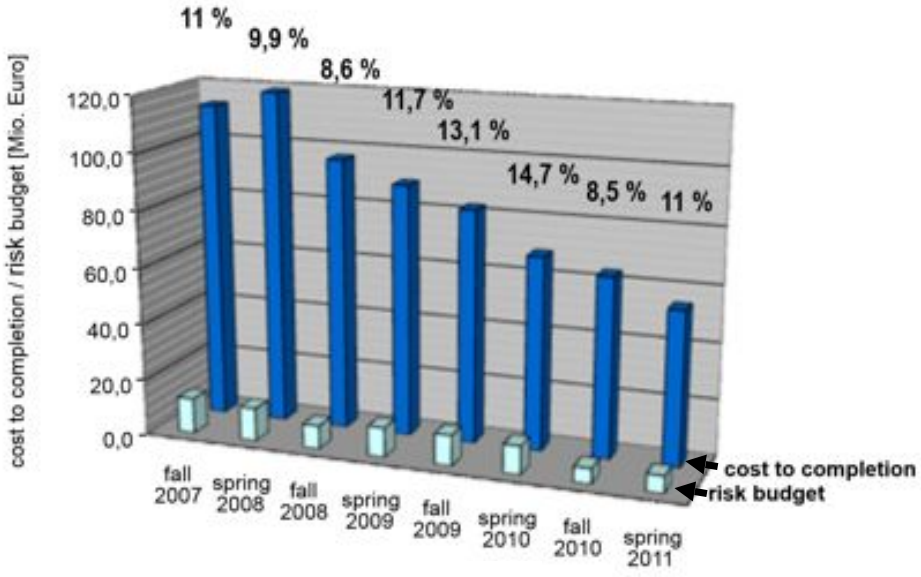
EVM Tool Implementation

- Implement early in the project
- Maintain high data quality of EVM inputs
- Clear definition of 'earning rules' for each activity
- EVM tool should interface with other project tools

Lesson 6: Cost Management

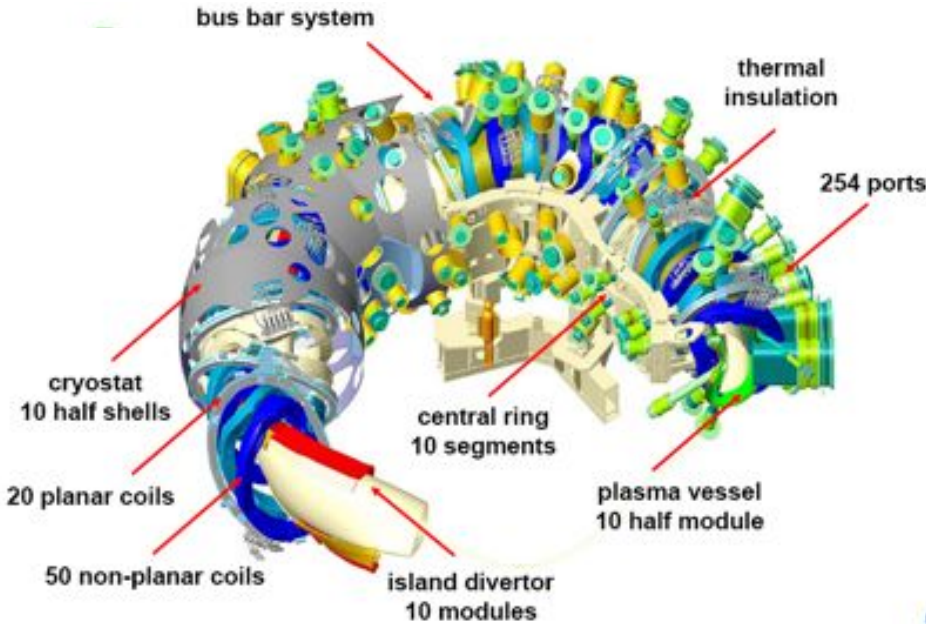
- *Minimize Cost Overruns Through Effective Contingency Planning and Less Optimistic Estimates*
  - Cost increases and delays damage relations with funding agencies and public
  - Use appropriate contingency reserves to avoid constant re-planning
  - Contingency reserves can expedite decision making

Project Contingency



Source: http://w3.pppl.gov/~neumeyer/SOFE/Presentations/SO4/SO4C-1%20Bosch.pdf

Complexity of W7-X

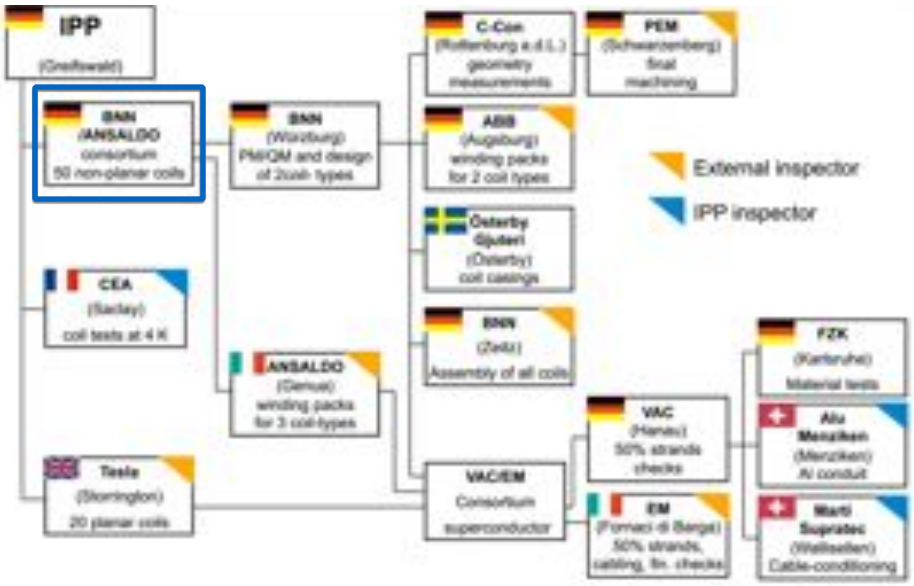


Lesson 7: Communication Management

- *Complex Systems Built by International Teams Require Effective Communication Channels*
  - Use virtual teams to bring expertise to the project
  - Information management tools should be flexible
  - W7-X used over 600 companies
  - Need a clear work breakdown structure

Source: http://w3.pppl.gov/~neumeyer/SOFE/Presentations/SO4/SO4C-1%20Bosch.pdf

W7-X Coils – European Consortium



Source: http://w3.pppl.gov/~neumeyer/SOFE/Presentations/SO4/SO4C-1%20Bosch.pdf

Lesson 8: Scope Management

- *Small Scope Creep Leads to Big Overall Changes*
  - Complex structure, large number of components
  - Inter-connected, co-dependent design
  - High precision, tight tolerance work
  - Schedule & cost overran as the project better understood technical requirements and risks

Lesson 9: Quality Management

- *Use Quality Assurance Plans to Control All the Work and Test Steps*
  - Based on ISO 9001 Standard
  - Multiple levels of Quality Management
    - Highly skilled project team
    - Qualified manufacturers to construct the components
    - Certified QA Inspectors
  - Structured gated approval process for each step of design, manufacturing and assembly

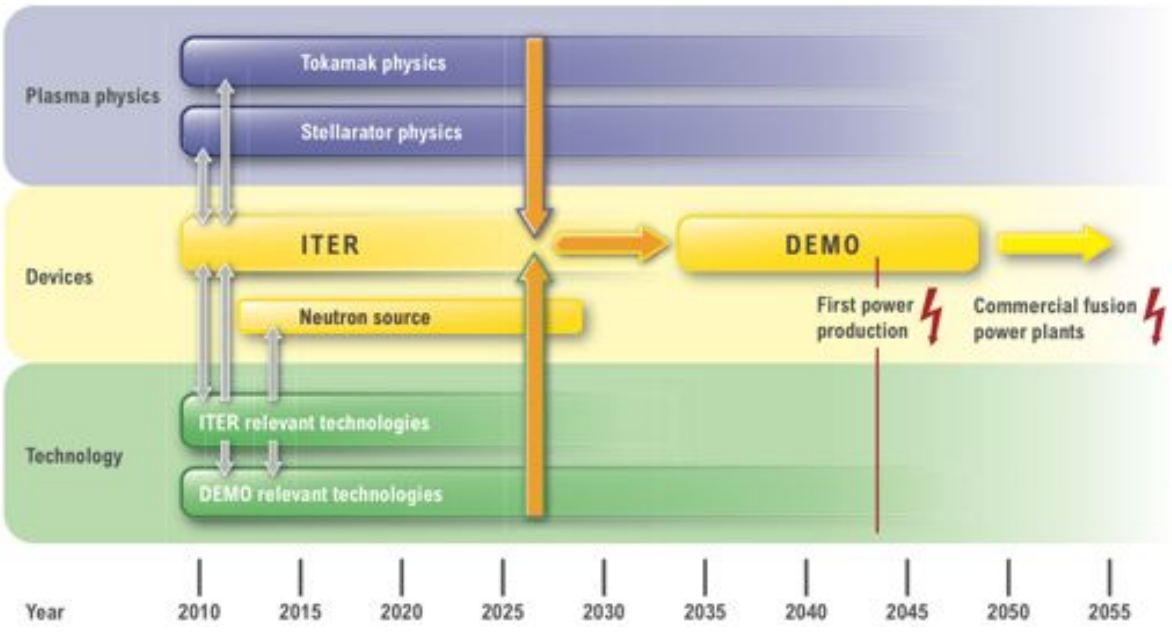
Summary

- W7-X faced many technical and financial challenges
- Allocate realistic schedule & cost contingencies
- Conduct thorough risk assessment
- Apply EVM tools from the beginning
- Practise effective communication & quality management
- Assembly of W7-X will be complete by the end of 2014. First plasma is scheduled for 2015

Questions

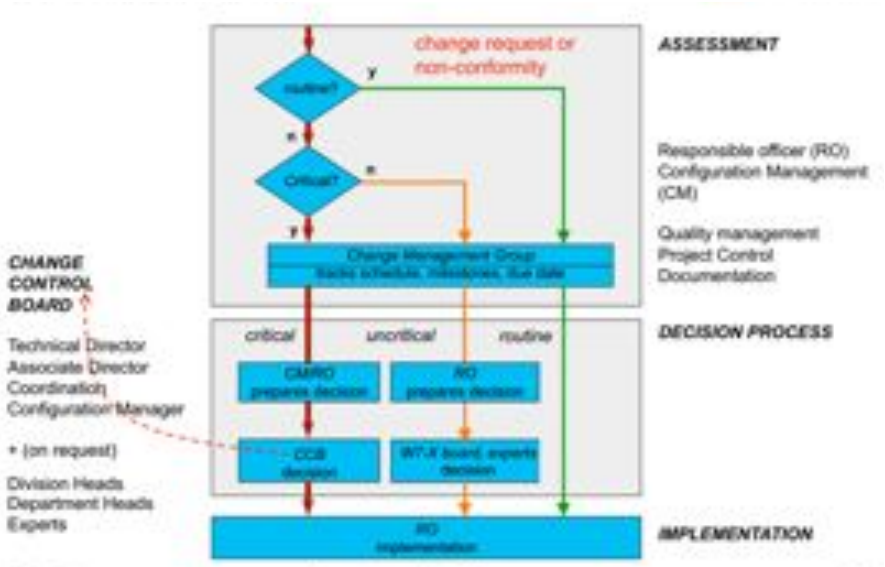
Super conducting coils

Source: http://w3.pppl.gov/~neumeyer/SOFE/Presentations/SO4/SO4C-1%20Bosch.pdf



Source: Max-Planck-Institut für Plasmaphysik: Fusion Basics

Lesson 11: Change Management



Lesson 11: Change Management

- *Change request must be investigated thoroughly and implemented quickly if appropriate*
  - Each change may affect scope, schedule, cost, quality, and risk
  - Design changes in the design phase should be implemented quickly before building starts
  - Management process changes welcome during the execution of the project as project team learns more of the project with increasing certainties