Documentation and Progress Tracking of Installation Activities

Examples and Lessons Learned from the European XFEL Project

Lars Hagge
Deutsches Elektronen-Synchrotron DESY
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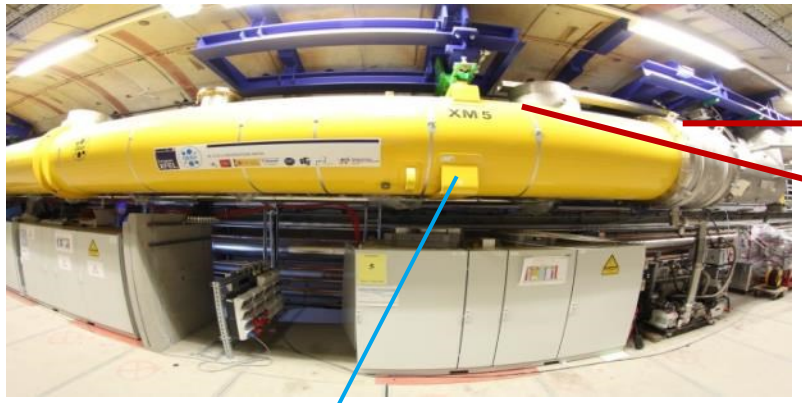
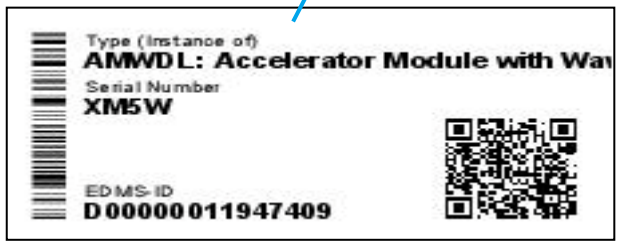
Agenda

- Concept and Objectives
- Interim: XM Assembly
- What: Product Structure
- How: Installation Process
- Relating Product Structure and Process
- Lessons Learned

Documentation for Installation Support & Progress Tracking

Inventory: Which parts are present in the tunnel, how are they id'ed & labelled?





Structure: Which parts have to be installed in the tunnel, how are they assembled?

Level	Serial Nr	Desicription
1	L1	L1 Instrumented Cryosectior
2	CS1	CSS Cryostring Short
3	XLST1FC1-IF	FCIF: Feed Cap Interface
3	A2.1.L1	MAML: Mounted Accelerato
4	XM5W	AMWDL: Accelerator Module
5	XM5	XM: XFEL Cryomodule
5	WD_003	WDL: Waveguide Distributio
4	1311/1312	CFF: Module Ceiling Frame v
4	1316/1317	LCFL: Long Module Ceiling Fr
3	MC_CFB-A2.1	MC: Module/Cap/SCB Conne
3	A2.2.L1	MAMR: Mounted Accelerato
3	MC_A2.1-A2.2	MC: Module Connection
3	A2.3.L1	MAML: Mounted Accelerato
3	MC_A2.2-A2.3	MC: Module Connection
3	A2.4.L1	MAMR: Mounted Accelerato
3	MC_A2.3-A2.4	MC: Module Connection
3	MC_A2.4-CTB	MC: Module/Cap/SCB Conne
3	XLST1EC1LP-IF	ECIF: End Cap Interface
2	FC1.L1	MFC: Mounted Feed Cap
2	EC1.L1	MEC: Mounted End Cap

Process: Which intermediate states shall be tracked for each part?

- Planning
- Reserved
- Occupied
- Aligned
- Completed

- Planning
- Aligned
- Connected (Cryo 1)
- Connected (Vacuum)
- Connected (Cryo 2)
- Completed

Objectives

- Technical Documentation shall be created for a purpose

- **Planning** the intended result and the necessary work
- **Organizing** the teams and their activities
- **Monitoring** progress and handling exceptions
- **Informing** about decisions, instructions, technical properties, history …

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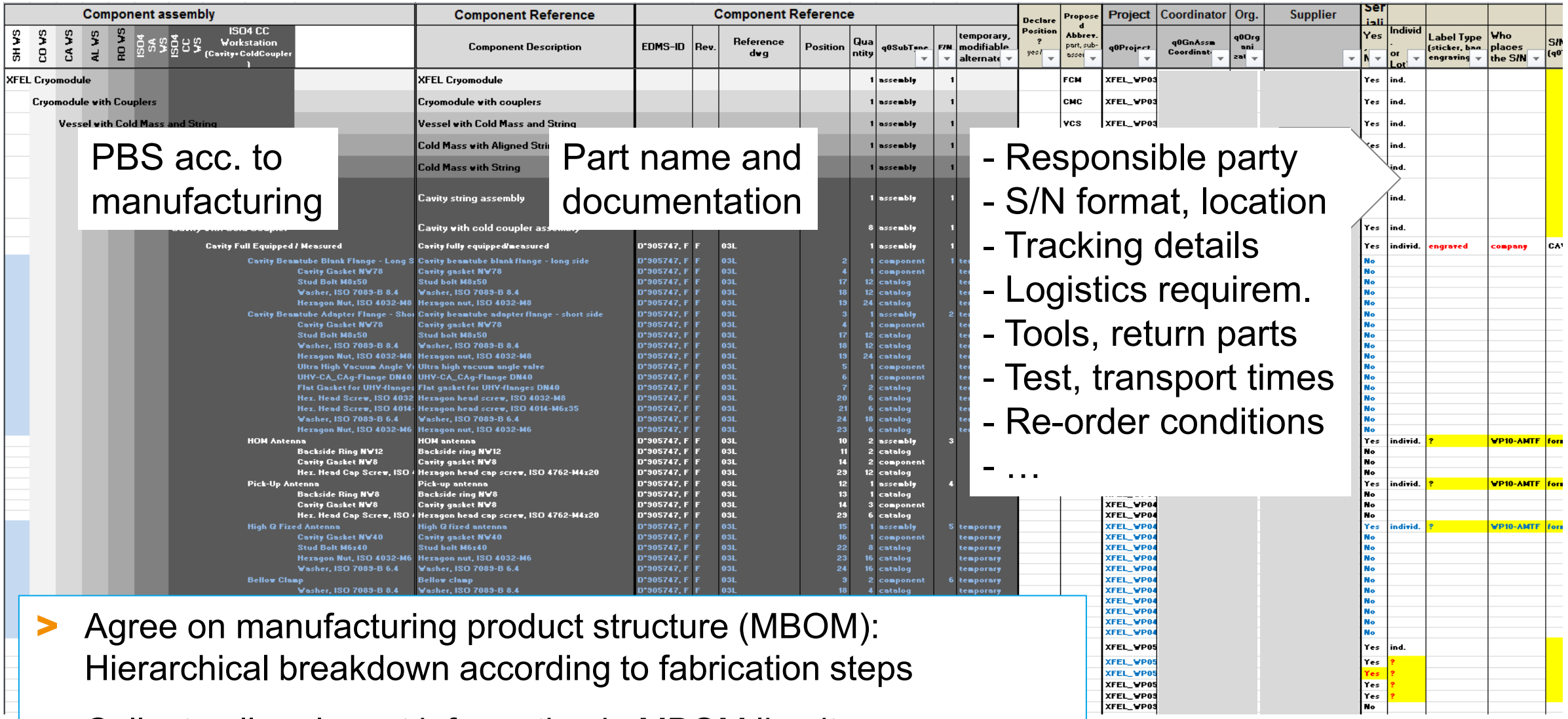
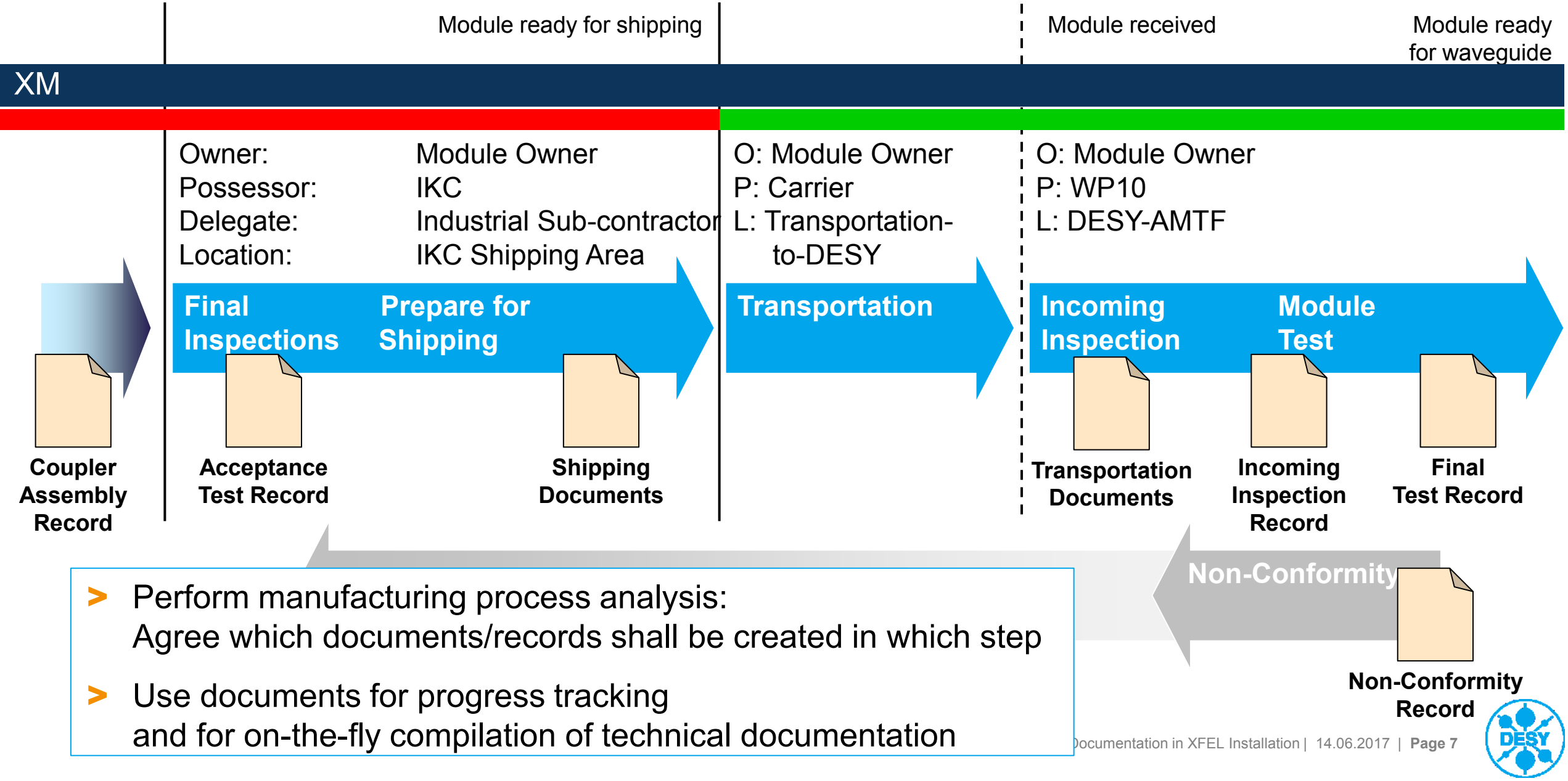
What: Product-Structure-Based Fabrication Planning



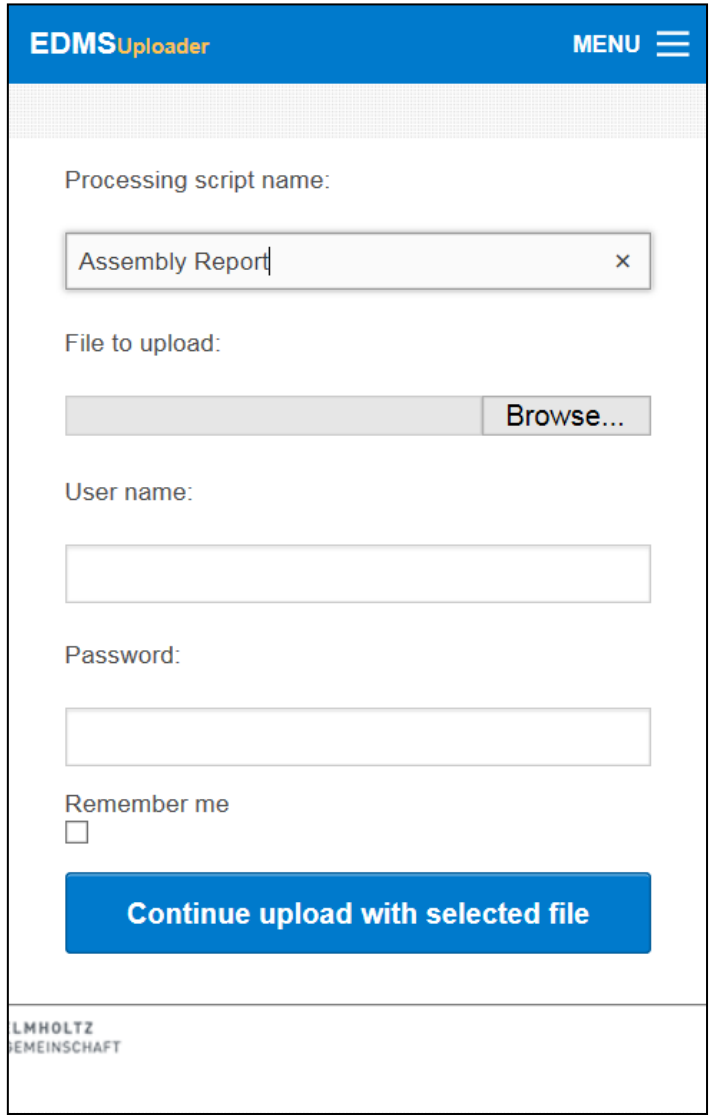
- Agree on manufacturing product structure (MBOM): Hierarchical breakdown according to fabrication steps
- Collect –all– relevant information in MBOM line items: responsibilities, sourcing, logistics, …

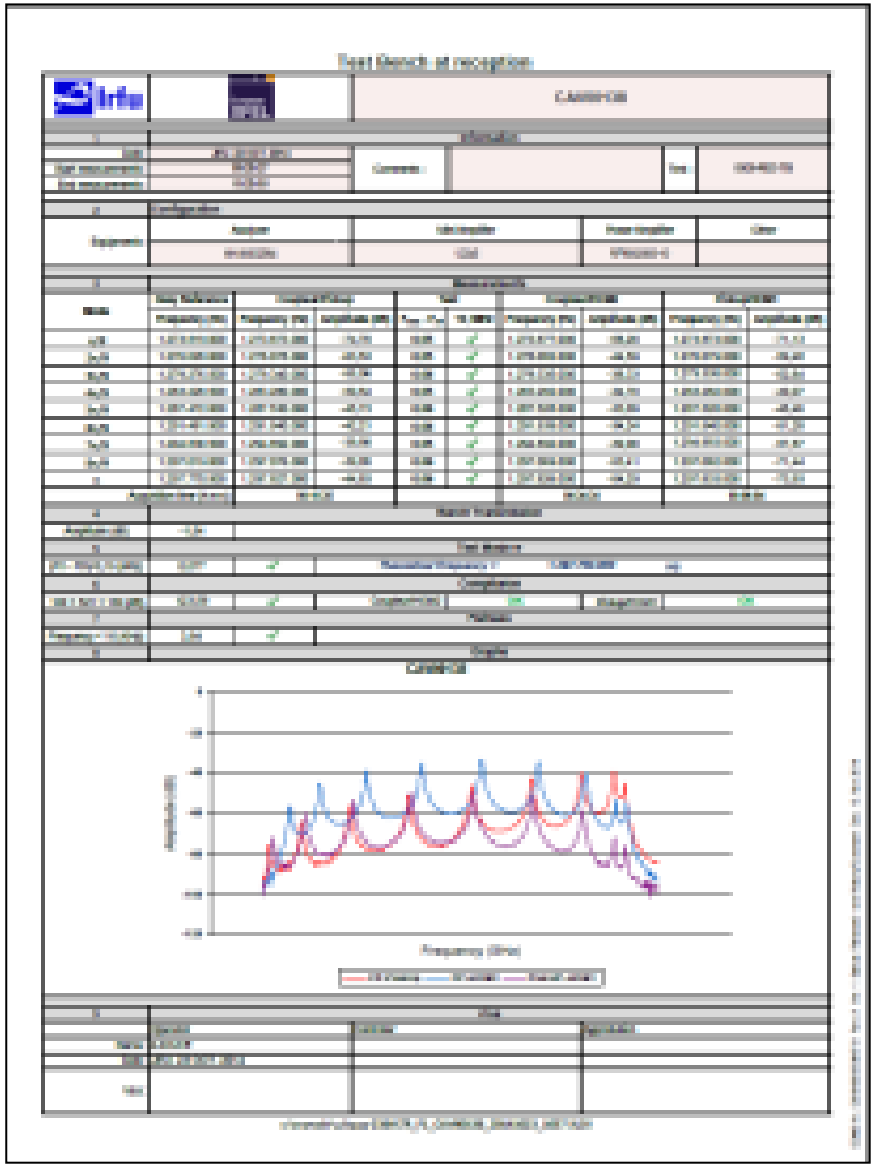
How: Manufacturing Process and Acceptance Testing



- Perform manufacturing process analysis:
  Agree which documents/records shall be created in which step
- Use documents for progress tracking
  and for on-the-fly compilation of technical documentation

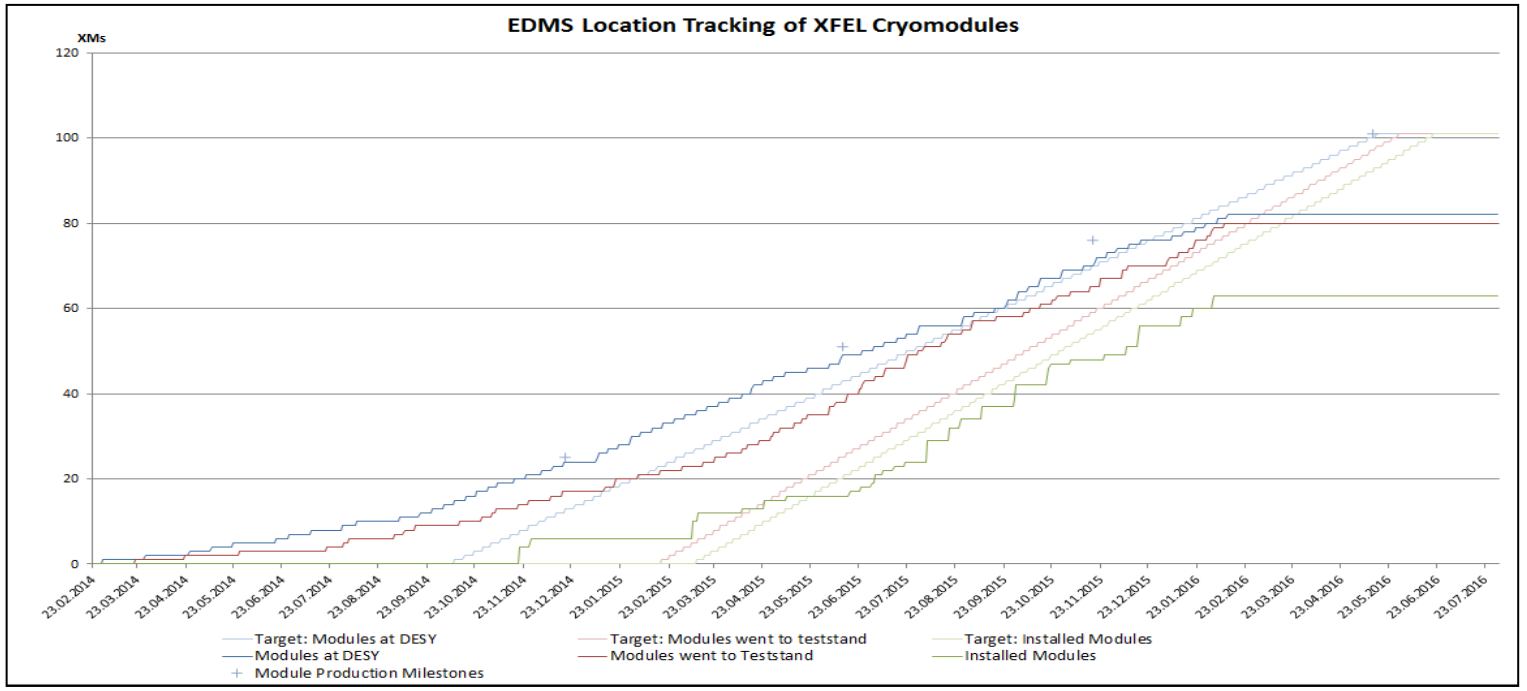
Tools: Capture Documents – Anywhere, Anytime, Anyhow





- Excel-based work record → easy to use:
- Work instructions for standardizing activities
  - Can be updated by users, e.g. add instructions, pictures
- Checklist & color-coding for recording results
- Automatic post-processing in EDMS
  - Update part status, location …
  - Forward to downstream database, application

Reporting and Analysis



As-Designed			As-Built				
Fabrication Part	Name	Parent Fabrication Part	Serial Number	Lot Number	Physical Part	Parent Physical Part	Status
D000000000572667,A,1,1	Gate Valve Assembly Set	D000000000572107,A,1,1	---	VGV Assy Set Lot E	D000000012035389,A,1,1	D000000012041229,A,1,1	Alternate
D000000000585947,A,1,1	BPMC: Button BPM for Croymodule	D000000000572497,A,1,1	BPMR-002	---	D000000010857259,A,1,1	D000000011515569,A,1,1	Alternate
D000000000573307,A,1,1	Cab-BPMC: BPM1 Cable	D000000000572087,A,1,1	05-BPMR	---	D000000010758619,A,1,1	D000000012064889,B,1,2	Alternate
D000000000575127,A,1,1	Capacitor Assembly CA-001	D000000000572067,A,1,1				D000000011262619,B,1,2	Deficient

NCRs in Physical Part S

Jun 13, 2017

EDMS ID	Name
D000000011262619,B,1,2	XM: XFEL Cryomodule

Non-Conformity-Reports and affe

Non-Conformity-Report					Affect
EDMS ID	Name	Description	Dispos. Code	Status	EDMS
D000000001116015,A,1,1	CEA-XFEL-RNC-15-516	THRI-WP-419: Wrong type of DN100 seal mounted on THRI-WP-419	Repair	Closed	D00000
D000000001116035,A,1,1	CEA-XFEL-RNC-15-547	THRI-WP-485: Wrong type of DN100 seal mounted on THRI-WP-485	Repair	Closed	D00000
D000000001128675,A,1,1	CEA-XFEL-RNC-15-517	XM25_CPL: Two clamps with stud are defective	Return	Closed	D00000
D000000001116005,A,1,1	CEA-XFEL-RNC-15-512	EZ015: Dirt on Cold Mass EZ015	Use As Is	Closed	D00000
	CEA-				

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Installation MBOM & Inventory

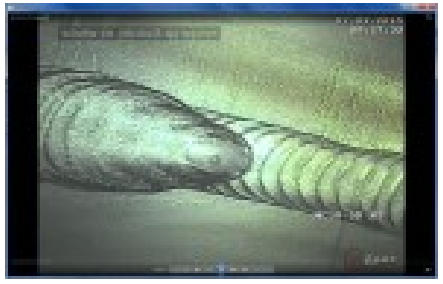
EDMS-ID	Name
D00000000680647	L1 Instrumented Cryosection
D00000000677627	CSS Cryostring Short
D00000000677247	MAML: Mounted Accelerator Module Left
D00000000676627	AMWDL: Accelerator Module with Waveguide Distribution
D00000000676507	AM: Accelerator Module
D00000000676907	WDL: Waveguide Distribution Left
D00000000681517	AMC: Accelerator Module Cabling
D00000000677487	CFL: Module Ceiling Frame with Suspension, Loose point
D00000000679787	CFF: Module Ceiling Frame with Suspension, Fixed point
D00000000677367	MAMR: Mounted Accelerator Module Right
D00000000663977	MC: Module Connection
D00000000680037	MC: Module/Cap/SCB Connection
D00000000682247	CIFF: Connection Box Half (Interface Feed)
D00000000682417	CIFE: Connection Box Half (Interface End)
D00000000681157	MFC: Mounted Feed Cap
D00000000681047	MEC: Mounted End Cap

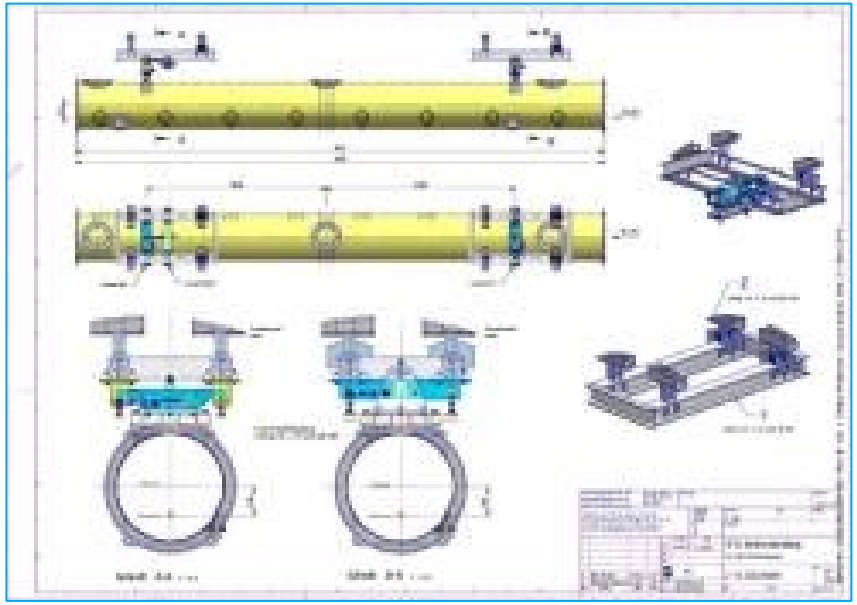
D00000012067429,A,1,1	L1	L1 Instrumente
D00000012184269,A,1,1	FC1.L1	MFC: Mounted
D00000012184329,A,1,1	EC1.L1	MEC: Mounted
D00000012067389,A,1,1	CS1	CSS Cryostring
D00000012159969,A,1,1	XLST1FC1-IF	FCIF: Feed Ca
D00000012088309,A,1,1	MC_CFB-A2.1	MC: Module/Ca
D00000012036129,A,1,1	A2.1.L1	MAML: Mounte
D00000011947409,A,1,1	XM5W	AMWDL: Accel
D00000011262219,B,1,2	XM5	XM: XFEL Cryo
D00000011744449,A,1,1	XM5_VCMS	VCMS: Vessel
D00000011744469,A,1,1	XM5_VVS	VVS: Vacuum
D00000011717799,A,1,1	XM5_CMAS	CMAS: Cold M
D00000011717579,B,1,2	XM5_CMS	CMS: Cold Ma
D00000011633089,A,1,1	XM5_STR	STR: Cavity St
D00000011632849,A,1,1	CCC90	CCC: Cavity +
D00000011301589,A,1,1	THRI-CP-212	CCP: Coupler
D00000011460279,B,1,2	CAV_FE00090	Cavity full equ
D00000010693389,A,1,1	XPA00423	PU: Pick-Up A
D00000010667149,A,1,1	XHA00927	HOM: HOM A
D00000010662249,A,1,1	XHA00682	HOM: HOM A
D00000011204089,A,1,1	CAV_HT00090	Cavity in heliu
D00000011147129,A,1	SC01187	Sliding collar
D00000011146509,A,1,	HT01187	Helium tank
D00000011204069,A,1,	CAV_RB00090	Cavity with rin
D00000011145889,A,1	AD01187	Adapter
D00000011240819,A,1,1		Tuner Ring

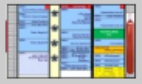
- Installation MBOM lists “Accelerator Module” as leaf part.
- After installation, physical inventory contains configuration of installed module “down to cavities and Nb sheets”

Documents and Reports

- Same approach as in production:
  MBOM → documents → reports
- Different types of documents and different reports, but same technical solution.

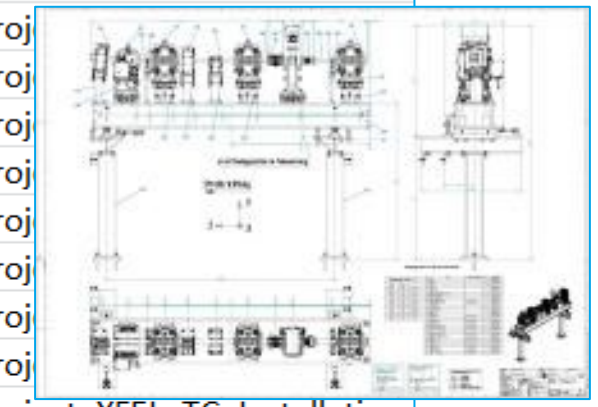


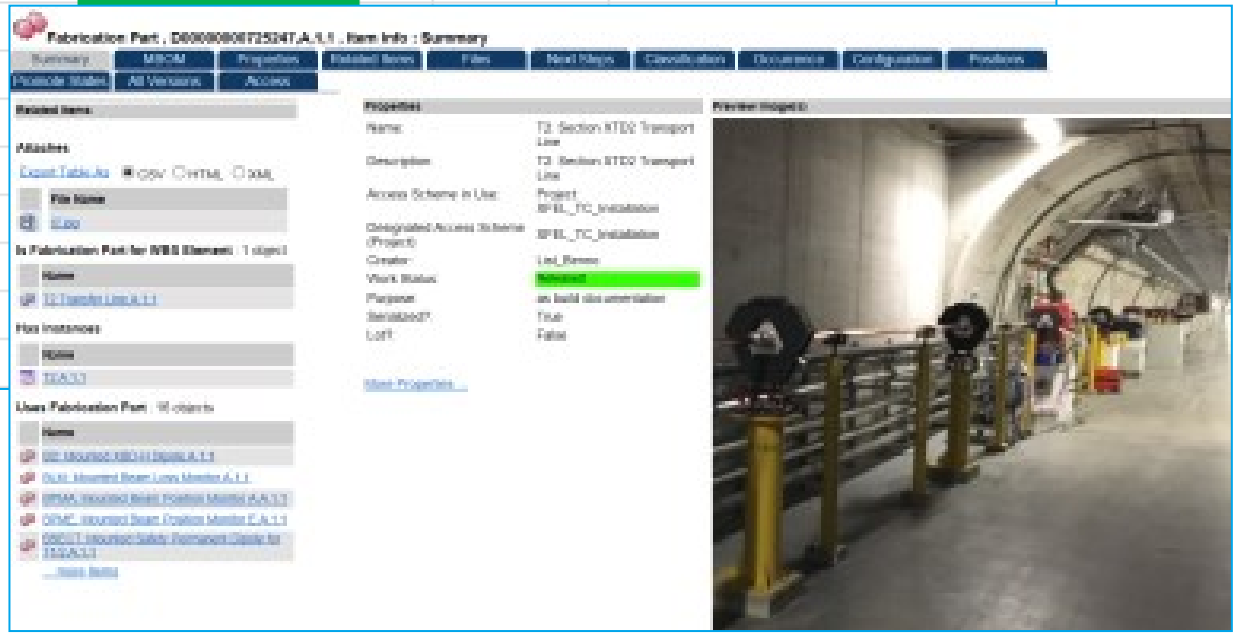


Part	Name	Sections				
		Cryostrings				
		RF-Stations				RFS-Linac-RF-Station08-00 not f
	Work Progress					
	Cryostrings					
						
MAML/R	Mounted Module			A9.1.L3 Pre-Aligned	A9.2.L3 Pre-Aligned	A9.3.L3 Pre-Aligned
CFL	Support Frame Loose End	TC		982/983 Completed	974/975 Completed	966/967 Completed
CFF	Support Frame Fixed End	TC		977/978 Completed	969/970 Completed	961/962 Completed
MWDL/R	Cryomodule	MO		XM31 Released	XM28 Released	XM34 Released
MC	Module Connection	WP03		MC_A9.1-A9.2 Released	MC_A9.2-A9.3 Released	MC_A9.3-A9 Released
	Cryo-Box	WP13	XLST3SC1LP/XLST4SC1JV Completed			
	Cryo-Box Connection	WP13	MC_CSC-A9.1 Released			
	RF-Stations					
						
				Connecting WD	Klystron WD	Klystron
		WP01		Not occupied	Not occupied	Not occupied
	Racks					
							
			Cryo	LLRF I	RF	LLRF II
	Cabinet	TC	XTL_L3.A9_R01 Completed	XTL_L3.A9_R07 Completed	XTL_L3.A9_R15 not found	XTL_L3.A9_R Completed
	Equipped Rack (Generic)	TC	XTL_L3.A9_R01.1 Released	XTL_L3.A9_R07.1 Released	Not occupied	XTL_L3.A9_R Released
	Equipped Rack (Generic)	TC	XTL_L3.A9_R01.2 Released	XTL_L3.A9_R07.2 Released	Not occupied	XTL_L3.A9_R Planning
	Equipped Rack (Generic)	TC	XTL_L3.A9_R01.3 Released	XTL_L3.A9_R07.3 Released	Not occupied	XTL_L3.A9_R Released
	Rack Monitoring Unit	TC	XTL_L3.A9_R01.RMU Released	XTL_L3.A9_R07.RMU Released	Not occupied	XTL_L3.A9_R37 Released
	Rack Fire Extinguishing Unit	WP36	XTL_L3.A9_R01.RFEU Released	XTL_L3.A9_R07.RFEU Released	Not occupied	XTL_L3.A9_R37 Released
	Rack Power Supply Unit	TC	XTL_L3.A9_R01.RPSU Released	XTL_L3.A9_R07.RPSU Released	Not occupied	XTL_L3.A9_R37 Released
	Rack Cooling Unit	TC	XTL_L3.A9_R01.RCU Released	XTL_L3.A9_R07.RCU Released	Not occupied	XTL_L3.A9_R37 Released
	Rack Network Unit	WP34	XTL_L3.A9_R01.RNU Released	XTL_L3.A9_R07.RNU Released	Not occupied	XTL_L3.A9_R37 Released
	Rack Fibre Network Connection	WP34	XTL_L3.A9_R01.RFNC Released	XTL_L3.A9_R07.RFNC Released	Not occupied	XTL_L3.A9_R37 Released

Further Beamlines

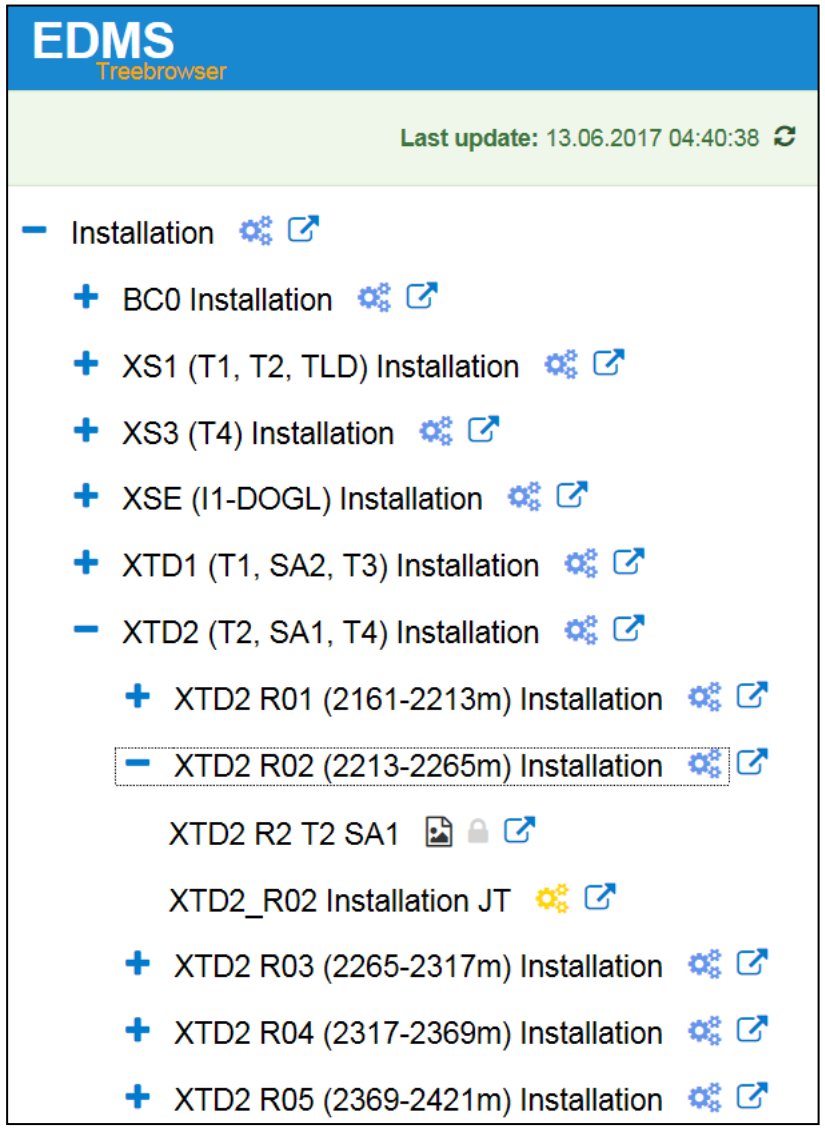
EDMS-ID	Name	Quantity	Work Status	F/N	Serialized?	Coordinator
D00000000725247	T2: Section XTD2 Transport Line		Released		TRUE	Proj
D00000000717767	BPMA: Mounted Beam Position Monitor A	11	Released	1	TRUE	Proj
D00000000717787	BPME: Mounted Beam Position Monitor E	2	Released	2	TRUE	Proj
D00000000721677	OTRB: Mounted Screen OTR-B	3	Released	3	TRUE	Proj
D00000000707977	TORA: Toroid A with RF screen	1	Released	4	TRUE	Proj
D00000000717857	BLM: Mounted Beam Loss Monitor	9	Released	5	TRUE	Proj
D00000000717447	BD: Mounted XBD-H Dipole	1	Released	6	TRUE	Proj
D00000000717347	CEX: Mounted XCE-H Corrector	2	Released	7	TRUE	Proj
D00000000717367	CFX: Mounted XCF-H Corrector	6	Released	8	TRUE	Project: XFEL_TC_Installation
D00000000717377	CFY: Mounted XCF-V Corrector					
D00000000721197	CNY: Mounted XCN-V Corrector					
D00000000717217	QA: Mounted XQA Quadrupole					
D00000000717247	QF: Mounted XQF Quadrupole					
D00000000724687	BSECT: Mounted Safety Permanent Dipole for T1/2					
D00000000725187	U40S: Mounted Sacrificial Undulator					
D00000000725587	T2-VAC: T1 Vacuum System					
D00000000725257	T2-MEC: T1 Mechanics and Support					

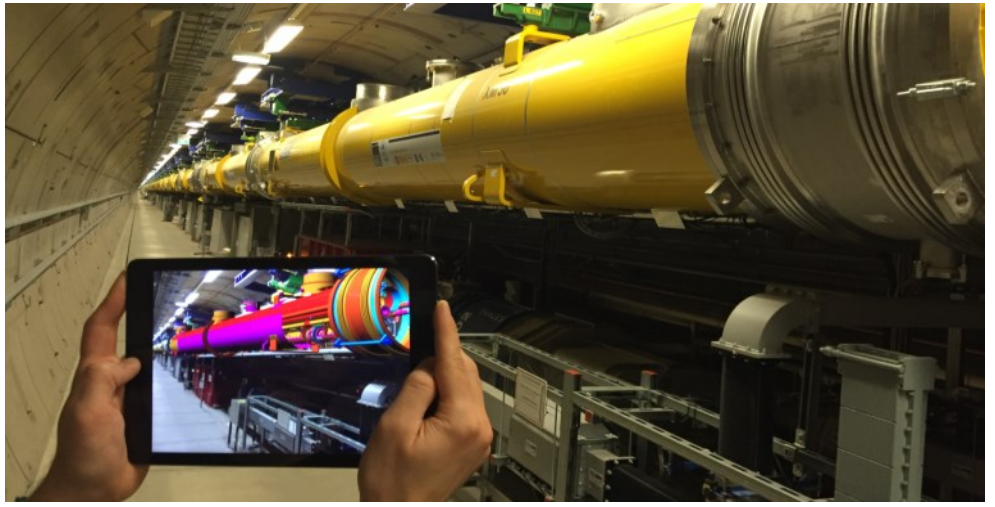




- Example MBOM for warm beamline section
- Beamlines are “individual products” → preparation effort for every section, different from series production of components

Mobile Access and Updates in the Tunnel





- Access installation drawings on tablets in the tunnel
  - navigate MBOM to tunnel location
- Request updates if add'l info needed
  - measurement, note, view …
  - Response time "in minutes", full release control observed

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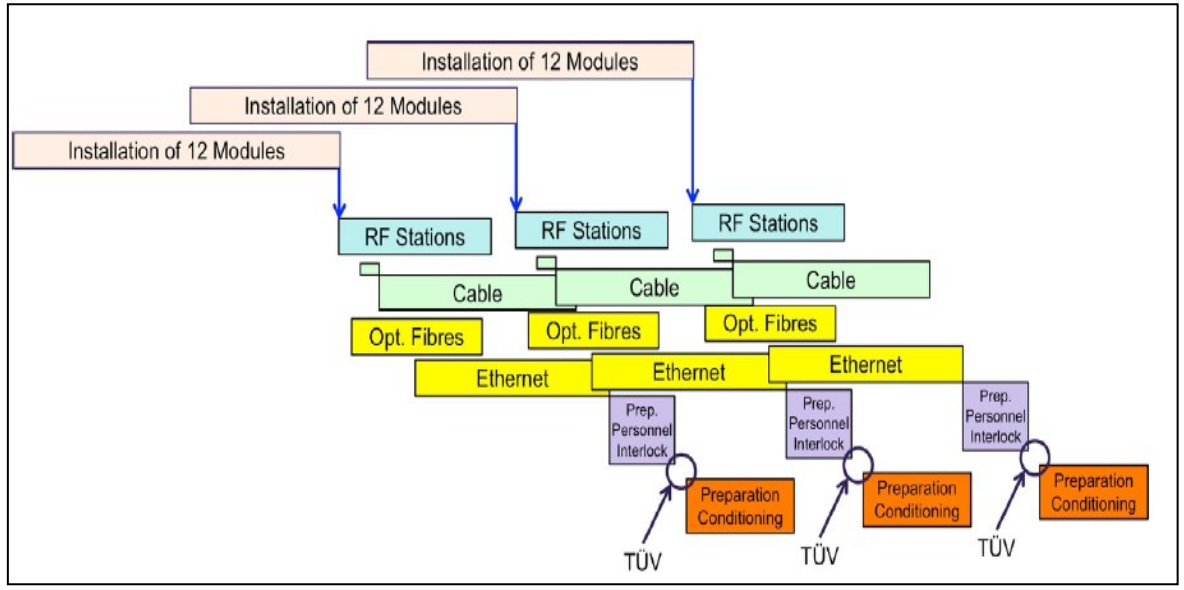
Installation Process Analysis

- **Objective: Establish commonly agreed installation procedure**
- Collect installation activities per group
- Develop sequence of activities
- Color code similar types of work
- Iterate with groups, identify potential for optimization
- Obtain approval from project management

M. Bousonville, F. Eints, S. Choroba, ref. IPAC16, IPAC17

Installation Process Analysis (2)

> Sequencing and Optimization



> Re-shuffle and parallelize activities, minimize frictions

> In-situ progress monitoring

> Weekly meetings collect status updates, review and confirm upcoming activities

High acceptance:
- Installation teams personally involved
- The right language (tasks, to-do's)
- Visualization

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Installation Process and Product Structure

Process: Which activities have to be performed in XTL, which parts do they affect?

mapping

Structure: Which parts have to be installed in the tunnel, how are they assembled?

Level	Serial Nr	Desicription
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3	A2.4.L1	MAMR: Mounted Accelerato
3	MC_A2.3-A2.4	MC: Module Connection
3	MC_A2.4-CTB	MC: Module/Cap/SCB Conne
3	XLST1EC1LP-IF	ECIF: End Cap Interface
2	FC1.L1	MFC: Mounted Feed Cap
2	EC1.L1	MEC: Mounted End Cap

Project: Project plan combines assignment of activities (scheduling) and completion of assemblies (milestones)

Mapping Product Structure and Process

1. Activity
2. Parts handled in by activity
3. Parts get installed?
4. Parts get processed?
5. New part status after processing

> Every step to result in part status change

> Every part to be accounted for in process

1 Process step	2 Corresponding part	3 Part installed	4 Promote state altered	5 Promote state after the step
1. Stahlbodenplatten installieren				
2. Modulrahmen anbringen und lackieren	CFL, CFF, LCFL, LCFF (ECF?, FCF?)	x		
3. Aufhängungen anreißen				
4. Hohlleiter montieren	Waveguide	x		
5. Module aufhängen und festziehen (Hytroc)	AMWDL/R	x		
	MAML/R		x	Occupied
6. ggf. Cryo-Box aufhängen	FC, EC, SCB	x		
	MFC, MEC, MSCB		x	Occupied
	CIFF, CIFE (connection box intreface parts)		x	Occupied
7. Module und Cryo-Box justieren	MAML/R		x	Pre-Aligned
	MFC, MEC		x	Pre-Aligned
8. Strahlvakuum - Übergang warme Sektion	CWT: Cold Warm Transition			
9. Stahlvakuum - Vorläufige Überwachung Strahlvakuum				
10. Pulstrafo aufstellen und anschließen (WP01,WP33)	Pulse Transformer Unit	x	x	Connected
11. Schweißen der Leitungen des 2K-Kreises und 8K-Rücklauf	MC		x	Connected (Cryo 1)
12. Strahlrohrverbindung (BLAMontage)	MC		x	Connected (Vacuum)

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Think in Lifecycles

- Every lifecycle phase conducts processes based on initial product definition, yields updated product documentation → Lifecycle contains BOMs and processes
  - Product Structure (BOM) ~ Product Definition = Agreement what to build; spec

- Product structures (BOMs) can be preserved and propagated along lifecycle, while processes are used up and to be newly analyzed at every stage → new teams, new reasoning
  - Ideally, BOM ~ BOM' ~ BOM'' ~ BOM'''
  - Failing to create one of the BOMs delays all further documentation activities

PowerPoint and Friends

- Technical documentation in PowerPoint, Confluence, Wikis, Web pages is very efficient …

Power Point is no Documentation

COLUMBIA
ACCIDENT INVESTIGATION BOARD

Engineering by Viewgraphs

The Debris Assessment Team presented its analysis in a formal briefing to the Mission Evaluation Room that relied on PowerPoint slides from Boeing. When engineering analyses and risk assessments are condensed to fit on a standard form or overhead slide, information is inevitably lost. In the process, the priority assigned to information can be easily misrepresented by its placement on a chart and the language that is used. Dr. Edward Tufte of Yale University, an expert in information presentation who also researched communications failures in the *Challenger* accident, studied how the slides used by the Debris Assessment Team in their briefing to the Mission Evaluation Room misrepresented key information.[38]

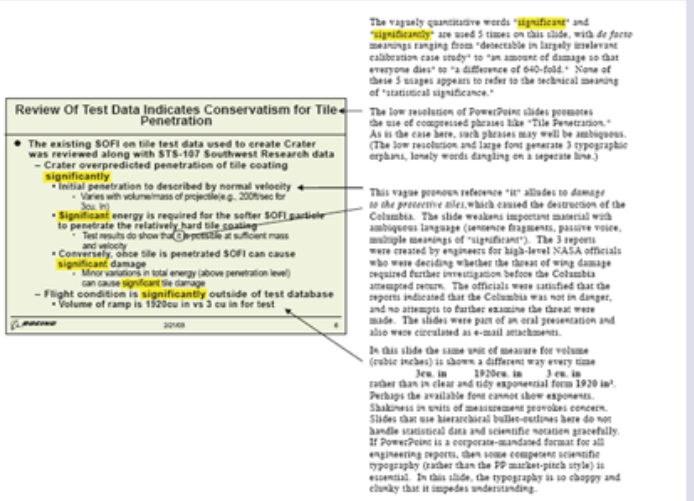
The slide created six levels of hierarchy, signified by the title and the symbols to the left of each line. These levels prioritized information that was already contained in 11 simple sentences. Tufte also notes that the title is confusing. "Review of Test Data Indicates Conservatism" refers not to the predicted tile damage, *but to the choice of test models used to predict the damage.*

Only at the bottom of the slide do engineers state a key piece of information: that one estimate of the debris that struck *Columbia* was 640 times larger than the data used to calibrate the model on which engineers based their damage assessments. (Later analysis showed that the debris object was actually 400 times larger). This difference led Tufte to suggest that a more appropriate headline would be "Review of Test Data Indicates Irrelevance of Two Models."[39]

Tufte also criticized the sloppy language on the slide. "The vaguely quantitative words 'significant' and 'significantly' are used 5 times on this slide," he notes, "with de facto meanings ranging from 'detectable in largely irrelevant calibration case study' to 'an amount of damage so that everyone dies' to 'a difference of 640-fold.' "[40] Another example of sloppiness is that "cubic inches" is written inconsistently: "3cu. In," "1920cu in," and "3 cu in." While such inconsistencies might seem minor, in highly technical fields like aerospace engineering a misplaced decimal point or mistaken unit of measurement can easily engender inconsistencies and inaccuracies. In another phrase "Test results do show that it is possible at sufficient mass and velocity," the word "it" actually refers to "damage to the protective tiles."

As information is passed up an organization hierarchy, from people who do analysis to mid-level managers to high-level leadership, key explanations and supporting information is filtered out. In this context, it is easy to understand how a senior manager might read this PowerPoint slide and not realize that it addresses a life-threatening situation.

At many points during its investigation, the Board was surprised to receive similar presentation slides from NASA officials in place of technical reports. The Board views the endemic use of PowerPoint briefing slides instead of technical papers as an illustration of the problematic methods of technical communication at NASA.



The analysis by Dr. Edward Tufte of the slide from the Debris Assessment Team briefing. [SOFI=Spray-On Foam Insulation]

See Report of Columbia Accident Investigation Board, vol I, p. 191 at http://caib.nasa.gov/news/report/volume1/default.html

At many points during its investigation, the Board was surprised to receive similar presentation slides from NASA officials in place of technical reports. The Board views the endemic use of PowerPoint briefing slides instead of technical papers as an illustration of the problematic methods of technical communication at NASA.

The New York Times **Magazine**

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PowerPoint Makes You Dumb

By CLIVE THOMPSON
Published: December 14, 2003

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WATCH TRAILER

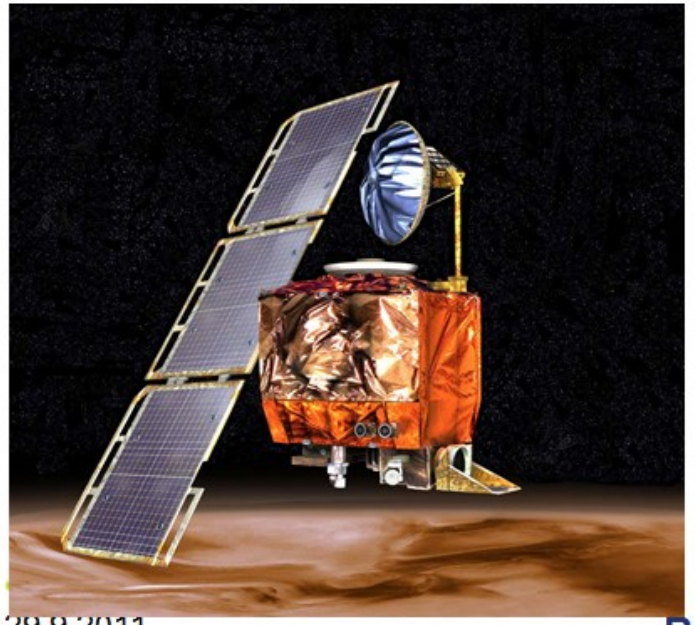
In August, the Columbia Accident Investigation Board at NASA released Volume 1 of its report on why the space shuttle crashed. As expected, the ship's foam insulation was the main cause of the disaster. But the board also fingered another unusual culprit: PowerPoint, Microsoft's well-known "slideware" program.

NASA, the board argued, had become too reliant on presenting complex information via PowerPoint, instead of by means of traditional ink-and-paper technical reports. When NASA engineers assessed possible wing damage during the mission, they presented the findings in a confusing PowerPoint slide -- so crammed with nested bullet points and irregular short forms that it was nearly impossible to untangle. "It is easy to understand how a senior manager might read this PowerPoint slide and not realize that it addresses a life-threatening situation," the board sternly noted.

Incomplete Specifications/Reviews Cost Money

The MCO MIB has determined that the root cause for the loss of the MCO spacecraft was the failure to use metric units in the coding of a ground software file, "Small Forces," used in trajectory models. Specifically, thruster performance data in English units instead of metric units was used in the software application code titled SM_FORCES (small forces). A file called Angular Momentum Desaturation (AMD) contained the output data from the SM_FORCES software. The data in the AMD file was required to be in metric units per existing software interface documentation, and the trajectory modelers assumed the data was provided in metric units per the requirements.

Mars Climate Orbiter Mishap INverstigation Board: Executive summary
ftp://ftp.hq.nasa.gov/pub/pao/reports/1999/MCO_report.pdf



Mars Climate Orbiter *1998 +1999
Project Cost: 655M$
Project Result: A new crater on Mars
Reason: Incomplete specs

R.I.P.

PowerPoint and Friends is not Technical Documentation

- Technical documentation in PowerPoint, Confluence, Wikis, Web pages is very efficient … but not effective:
  - Arbitrary: Level of detail, careful preparation, reviewed/controlled, focus/mix of topics …
  - Reassures authors (and readers) that extensive documentation is available – when it's not.
  - Can be dangerously misleading due to lack of precision
- "The magical 15 minutes": Technical information taking more than 15 minutes to follow-up …
  - is of longer-term relevance, will often see interrupts and staff changes when worked with,
  - should be prepared & managed adequately: proper documents, metadata/status, long-term availability
  - Anything of less than 15 minutes value can be kept in mails, presentations and wikis
- Or: Would you want to conduct a technical review on slides and wikis?

Maturity Model

- Maturity: Qualitative assessment of organization's capability to deliver the required services

depends on individuals	outcome can be reproduced	predictable regarding time, cost and quality	reliable & robust, also under heavy changes	performance is continuously improving

- Higher levels of maturity achieved by presence of e.g. procedures, instructions and reference documentation, continuously trained staff, regular comprehensive status reporting, standards …
- Methods and tools may evolve on-demand and bottom up, but maturity needs to be planned for and established top down.

Finally

Many major obstacles in XFEL project were solved by process analysis and visualization

D00000012067429,A,1,1	L1	L1 Instrume
D00000012184269,A,1,1	FC1.L1	MFC: Mount
D00000012184329,A,1,1	EC1.L1	MEC: Mount
D00000012067389,A,1,1	CS1	CSS Cryostr
D00000012159969,A,1,1	XLST1FC1-IF	FCIF: Feed
D00000012088309,A,1,1	MC_CFB-A2.1	MC: Module
D00000012036129,A,1,1	A2.1.L1	MAML: Mou
D00000011947409,A,1,1	XM5W	AMWDL: Ac
D00000011262219,B,1,2	XM5	XM: XFEL C
D00000011744449,A,1,1	XM5_VCMS	VCMS: Ves
D00000011744469,A,1,1	XM5_VVS	VVS: Vacuu
D00000011717799,A,1,1	XM5_CMAS	CMAS: Cold
D00000011717579,B,1,2	XM5_CMS	CMS: Cold
D00000011633089,A,1,1	XM5_STR	STR: Cavity
D00000011632849,A,1,1	CCC90	CCC: Cavity
D00000011301589,A,1,1	THRI-CP-212	CCP: Coupl
D00000011460279,B,1,2	CAV_FE00090	Cavity full e
D00000010693389,A,1,1	XPA00423	PU: Pick-Up
D00000010667149,A,1,1	XHA00927	HOM: HOM

Central activities were successful when performed by teams involved in project activities
→ Provide central services*) (in a collaborative spirit and with local infrastructure)
- Will receive acceptance
- Will allow to seamlessly introduce methods and tools

*) *read: contribute by doing real work*