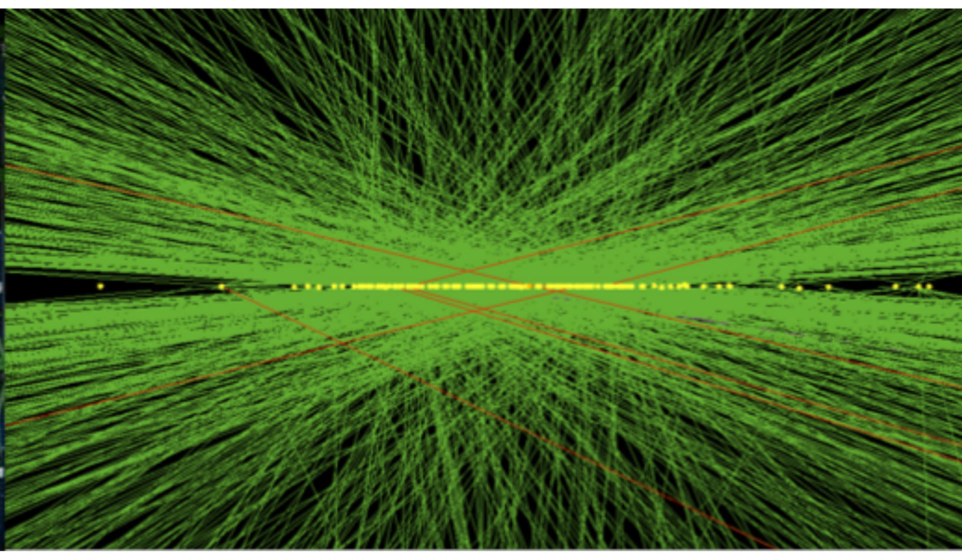
Science Goals to Requirements and International CMS Role in QA

Christopher S. Hill, Project Scientist

ESH and QA Review

November 29, 2018



Outline

- Biographical sketch
- Science Flowdown to Requirements
- Example of Requirements Documentation
- International QA process
- Summary

Biographical Sketch

- Chris Hill
  - Professor, Ohio State University
  - CMS Phase 2 Tracker Management Board (2015 – 2016)
  - **CMS Deputy Physics Coordinator (2012 – 2013)**
    - *ex officio* CMS XEB, CMS MB, **Upgrade Physics Coordinator**
  - CMS Exotica Convener (2010 – 2012)
  - USCMS Phase 2 R&D Steering Committee (2013 – 2014)
  - CDF Run II Silicon Detector Project Leader (2001 – 2002)
  - Experience with design/construction/commissioning of numerous Si projects
    - CMS Tracker Outer Barrel, CMS Phase 1 FPIX
    - CDF Run IIa, L00/ISL/SVXII, CDF Run IIb
  - USCMS L2 HL-LHC Tracker PM (2015 – 2016)
  - ***USCMS HL-LHC Project Scientist (2016 –)***

Science Flowdown

- In preparation for CD1, formalized the science flowdown to technical requirements
  - Established requirements via R&D, implemented systems for documentation, tracking, verification, and change

- We recognize the following levels (highest to lowest):

High

  - **Science Drivers** - these come from the P5 report and are broad scientific questions that multiple HEP experiments are trying to address in different ways
  - **Science Goals** - these are the more specific scientific questions that we will address with CMS
  - **Science Requirements** - these are the CMS wide (i.e. multiple sub-detectors involved) performance requirements that CMS needs to meet in order to achieve the science goals
  - **Science-Engineering Requirements** - these are US CMS sub-project specific performance requirements that a given L2 project needs to meet in order for the whole of CMS to meet the science requirements
  - **Engineering Requirements** - these are the technical/safety requirements that a particular US CMS L2 subproject needs to meet with its designs in order for the science-engineering requirements to be met

Low

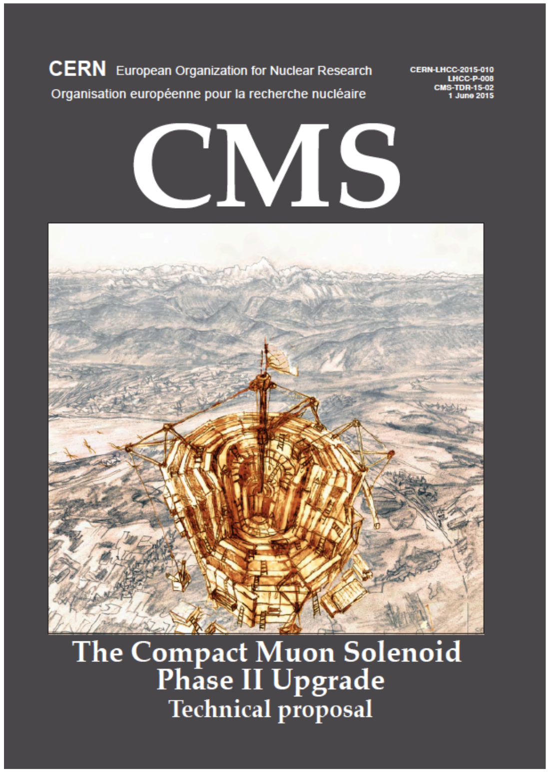
External to CMS

International CMS & US CMS Project Scientist

QA program designed to meet these

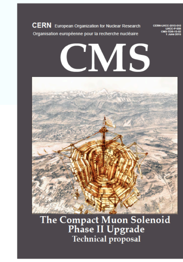
Requirements come from iCMS

- Science, science-engineering requirements **necessarily** determined at the international level
  - Many engineering requirements also
- Science requirements *but most engineering requirements* were *not yet* specified in the *CMS Phase II Upgrade Technical Proposal* (CERN-LHCC-2015-010)
- In 3 yrs since, significant R&D by CMS, (including many of us in U.S. CMS) established engineering requirements for sub-system level *Technical Design Reports (TDRs)*
- With these TDRs, iCMS experiment established the baseline design and documented the performance expectations for each sub-detector
  - Collectively these documents, in turn, establish science, science-engineering, and engineering requirements that the US CMS project scope must meet

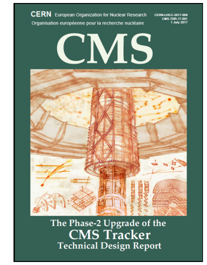


CERN-LHCC-2015-010
https://cds.cern.ch/record/2020886

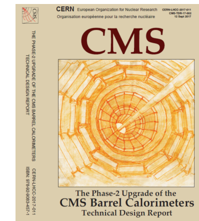
Status of TDRs



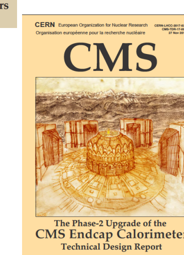
Subsystems



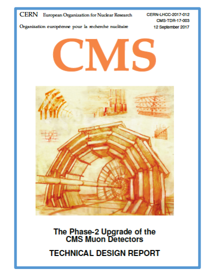
1. Tracker: consists of Outer Tracker and Inner (Pixel) Tracker
   - **Tracker TDR**: https://cds.cern.ch/record/2272264. UCG report: https://cds.cern.ch/record/2295762
   - Approved by CERN RB Dec. 4, 2017



2. Barrel Calorimeter: consists of hadronic and electromagnetic
   - **Barrel Calorimeters (TDR):** https://cds.cern.ch/record/2283187. UCG report: https://cds.cern.ch/record/2304338
   - Approved by CERN RB March 7, 2018



3. Endcap Calorimeter: both hadronic and electromagnetic parts
   - **Endcap Calorimeter (TDR)** https://cds.cern.ch/record/2293646. UCG report: https://cds.cern.ch/record/2313441
   - Approved by CERN RB April 18, 2018



4. Muon Systems: both hadronic and electromagnetic parts
   - **Muon Systems (TDR):** https://cds.cern.ch/record/2283189. UCG report: https://cds.cern.ch/record/2304341
   - Approved by CERN RB March 7, 2018
5. L1-Trigger; DAQ
   - L1-Trigger (interim-TDR): https://cds.cern.ch/record/2283192 **TDR Q1 2020**
   - DAQ/HLT (Interim-TDR): https://cds.cern.ch/record/2283193 **TDR Q2 2021**
   - Both iTDRs approved by RB Dec. 4, 2017
6. MIP Timing Detector
   - MIP Timing (Technical Proposal) : https://cds.cern.ch/record/2296612 **TDR Q1 2019**
   - TP approved by CERN RB March 7, 2018

CERN Review Committees/Boards: LHCC (Technical approval recommendation), UCG (Cost/Schedue/Risk approval recommendation), and RB (formal approval). LHCC and UCG report to RB.

Formalized Science Flowdown to Requirements

- We document the requirements flowdown as follows:
- Science Goals and Science requirements in one spreadsheet with two tabs,
  - cms-docdb.cern.ch docid=13337
  - Under project scientist control
- Sci-Engr and Engineering requirements in one spreadsheet *per L2 area* with two tabs,
  - cms-docdb.cern.ch docid=13388, 13447, 13318, 13536
  - Under L2 Manager, L2 SE control

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CMS Document 13337-v8

Science Requirements for US CMS HL-LHC

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Abstract:
This entry contains the controlled US CMS HL-LHC Project Science requirements. These are the top level science requirements derived from the experiment science goals which are also included in this document. Lower levels of science-engineering and engineering requirements are divided into the Project WBS Level 2 Systems

Files in Document:

- US HL-LHC CMS Sci Goals and Sci Requirements.xlsx (32.1 kB)

Get all files as tar.gz, zip.

Topics:

- Countries:USA:US HL-LHC Upgrades:Technical Scope
- Countries:USA:US HL-LHC Upgrades:Cost, Schedule, Risk
- Countries:USA:US HL-LHC Upgrades:Organisation
- Countries:USA:US HL-LHC Upgrades
- Countries:USA:US HL-LHC Upgrades:Reviews

Authors:

- Christopher Scott Hill

Referenced by:

- CMS-doc-13388: OT USCMS HL-LHC Systems Engineering
- CMS-doc-13447: Endcap USCMS HL-LHC System Engineering
- CMS-doc-13536: MIP Timing Layer HL-LHC Systems Engineering
- CMS-doc-13318: Trigger USCMS HL-LHC Systems Engineering

Viewable by:

- USCMS-MGMT
- USCMS-UP-REVIEWS
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CMS-doc-13337-v3 17 Aug 2017, 20:01
CMS-doc-13337-v2 16 Aug 2017, 21:55
CMS-doc-13337-v1 15 Jun 2017, 20:48

Sample of Requirements Documentation

Science Goals (example 1 of 4)

cms-docdb.cern.ch docid=13337

Title	ID	Type	Experimental Goal	Rationale
Higg Coupling Measurements	sci-goal-1	experimental objective	HL-LHC CMS is to achieve few percent measurements of the Higgs couplings and constraints on the its invisible width.	This is a HEP wide goal that follows from 1 of 5 P5 science drivers listed in the 2014 P5 report , namely to "use the Higgs boson as a new tool for discovery."

Science Requirements (example 1 of 14)

cms-docdb.cern.ch docid=13337

Title	ID	Type	Requirement	Parents
Primary Vertex Identification (and purity)	sci-req-7	requirement	Accurate reconstruction of Higgs decays requires accurate primary vertex identification (H to γγ). Accurate reconstruction is also necessary for DM candidates, rare SM processes, or BSM signals.	sci-goal-1, sci-goal-2, sci-goal-3, sci-goal-4

EC Science-Engineering Requirements (example 1 of 12)

cms-docdb.cern.ch docid=13447

Title	ID	Type	Requirement	Rationale	Parents
Precision timing of showers	EC-sci-engr-009	requirement	Showers reconstructed in both the silicon and scintillator sections of the EC shall have precise timing (~50 ps) for each shower with energy above 5 GeV	For good pileup mitigation, aid in identifying the primary vertex of the triggering interaction	sci-req-5, sci-req-6, sci-req-7, sci-req-8, sci-req-9, sci-req-10, sci-req-11, sci-req-12, sci-req-13, sci-req-14

EC Engineering Requirements (example 1 of 97)

cms-docdb.cern.ch docid=13447

ID	Title	Type	Requirement Text	Rationale/Notes	Parents
EC-engr-023	EC sensor time resolution	requirement	EC silicon cells shall have a time-of-arrival resolution of 50 ps or less throughout HL-LHC operation for each cell with collected charge > 10 fC	For pileup rejection, aid in particle flow reconstruction, and aid in identifying primary vertex and triggering interaction	EC-sci-engr-7, EC-sci-engr-9

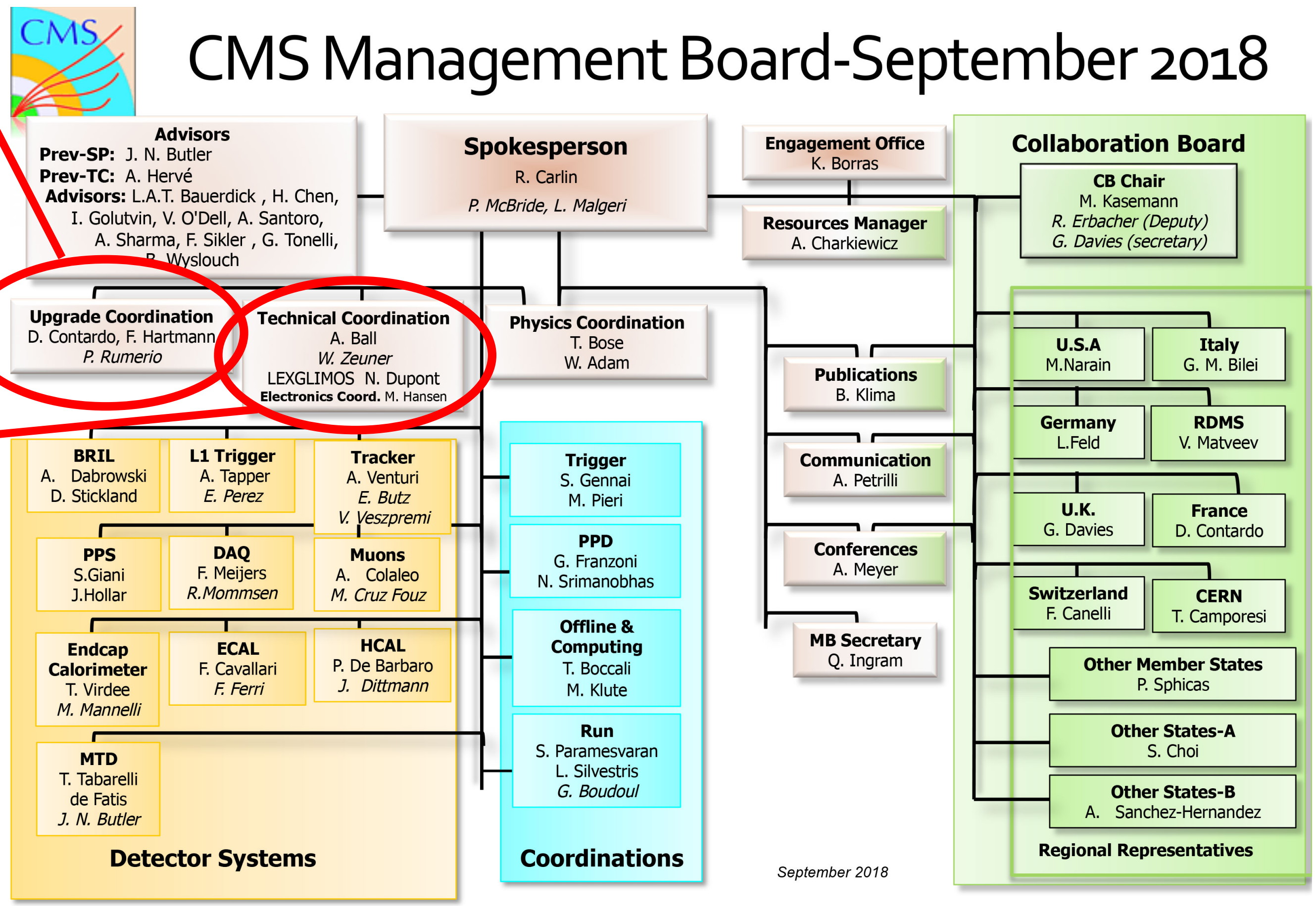
Programmatic Requirements

- Not all engineering requirements flow from science goals, some are "programmatic"
- ES&H requirements are of this kind
  - These are contained in the same L2 spreadsheets as those that flow from science, but do not have parents.
  - Example excerpts from OT (cms-docdb.cern.ch docid=13388)below:

ID	Title	Type	Requirement Text	Rationale/Notes	Parents
OT-engr-013	Outer Tracker System ES&H Personnel Injury and Equipment Damage	requirement	Component and tooling internal loads shall not exceed material allowables plus a factor of safety.	Factors of Safety may be facility dependent, early agreement must be made. Analyses and tests must be made to the worst case.	N/A, programmatic requirement
OT-engr-014	Outer Tracker System ES&H Electrical Hazards	requirement	All Project activities shall be shown to comply with international and US Electrical standards and regulations.	Following complete planning and engineering and PRIOR to commencing work on fabrication and/or test operation all systems components and the supporting documentation/data must be reviewed and compliance validated.	N/A, programmatic requirement
OT-engr-015	Outer Tracker System ES&H Mechanical Fluid Cooling Systems Hazards	requirement	All Project activities associated with mechanical fluid cooling systems shall be shown to comply with international and US ES&H standards and regulation.	Following complete planning and engineering and PRIOR to commencing work on fabrication and/or test operation all systems components and the supporting documentation/data must be reviewed and compliance validated.	N/A, programmatic requirement
OT-engr-016	Outer Tracker System Logistics - Transport	requirement	Component packaging shall be sufficient to prevent component damage during all forms of transport.	Verfication of this requirement need not exceed engineering judgment except in cases specifically identified by the Lead Systems Engineer.	N/A, programmatic requirement

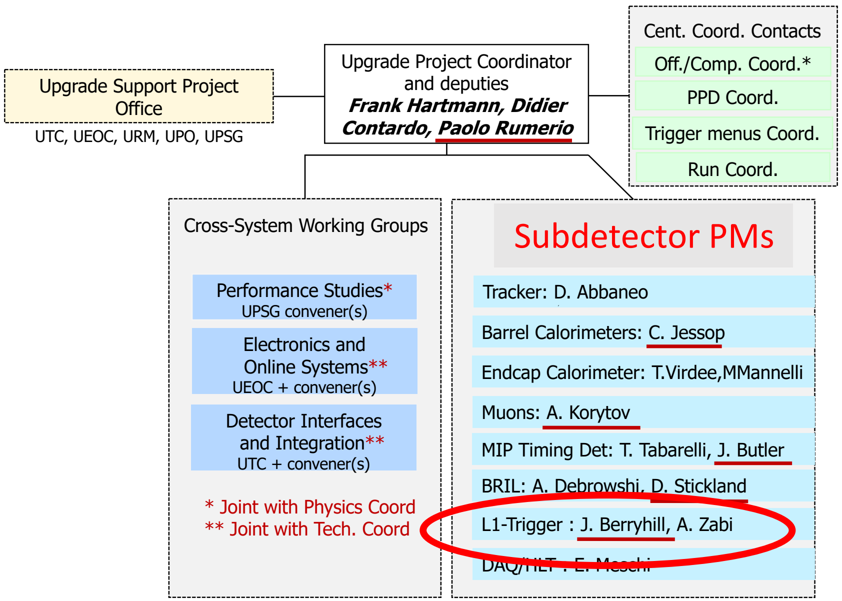
Relevant iCMS Management

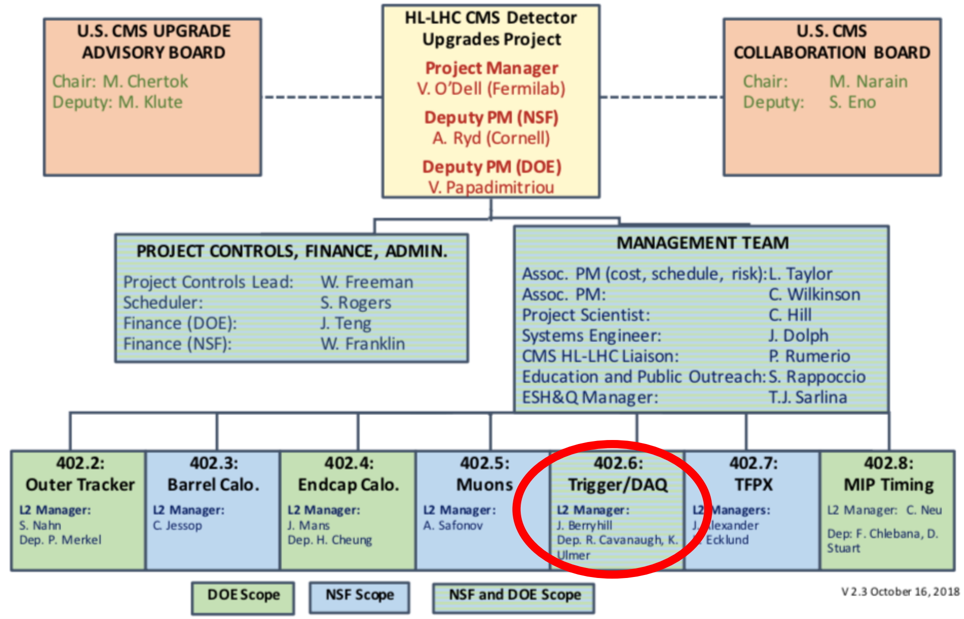
- CMS UC is ultimately responsible for scientific/technical requirements
  - In practice, delegated to subdetector PMs
- CMS TC is ultimately responsible for QA for technical & programmatic requirements
  - Delegated to subdetector PMs for implementation for non-safety reqs.
    - TC enforces through reviews
  - Formally delegated to LEXGLIMOS (CERN safety professional) for safety reqs.



UC = Upgrade Coordinator
TC = Technical Coordinator

Relationship with U.S. HL-LHC Project





- QA procedures for each CMS subdetector (e.g. L1 Trigger) established by relevant iCMS subdetector PM
- Corresponding U.S. CMS subproject L2 manager (e.g. 402.6) responsible for implementation, documentation, etc within U.S. project to satisfy **both** iCMS scrutiny **and** U.S. project/DOE requisites
- This is facilitated by the fact that in many cases one of the iCMS subdetector managers is a member of U.S. CMS
  - Sometimes, as in my example, this is the **same person** as the U.S. CMS L2

iCMS Approval Steps

- iCMS collaboration QA practices are embedded in the formal review and approval process described in the *LHC Experiments Phase II Upgrades Approval Process* [CERN LHCC-2015-007].
- *The following steps are required for **each** CMS subdetector in the Upgrade:*
- *Step 1: Initial Design*
  - review overall scope and cost for the entire upgrade program for each experiment, retaining the possibility for different options which may depend on technical issues and/or on funding availability. Approve readiness to proceed to Step 2. Step 1 is documented in the CMS Upgrade Technical Proposal [Ref-7] and Scope Documents [Ref-8].
- *Step 2: Baseline Design*
  - **review and approve Technical Design Reports** and QA plans for each subdetector. This documents the baseline scope, cost and schedule for the subsequent change control process.
- *Step 3: Final Design / Start of Construction*
  - **review and approve the final design** and the production of the major detector components, verifying that they meet the requirements and are compatible with the installation plan. Establish follow-up reviews/approvals for installation readiness.
- *Step 4: Installation and Commissioning*
  - review and approve the installation and commissioning of the major detector components. Evaluate the capability of the integrated detectors to provide the expected performance. Review and approve readiness for operations.
- *Each of these steps **includes review/approval at the CMS level, followed by review/approval by CERN LHCC/UCG and RB.***

I showed you the approval of the TDRs on slide 6, so we are roughly here

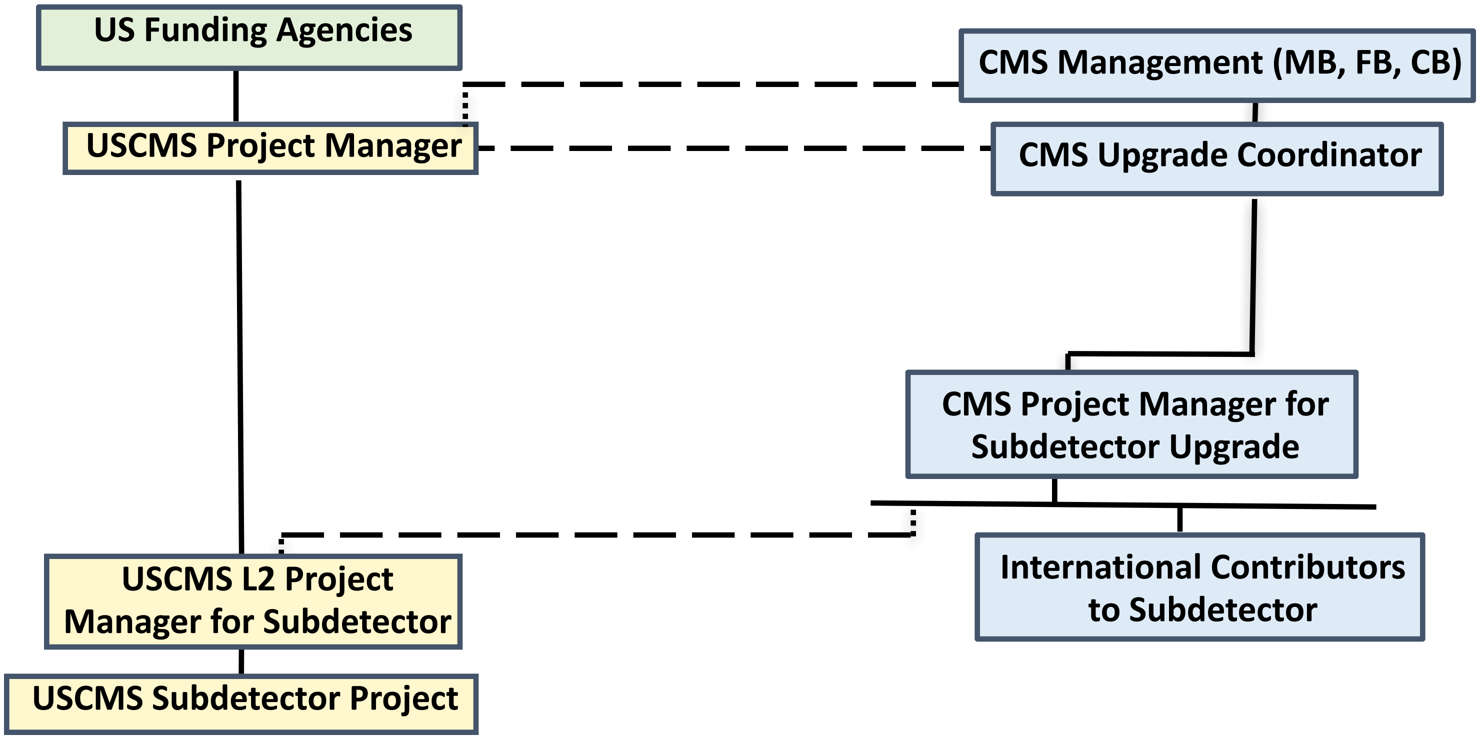
Summary

- iCMS Science Goals, Science Requirements and Engineering requirements defined/refined by R&D over past year(s)
  - Documented in TPs + TDRs for each sub-system
  - Documents reviewed by LHCC/UCG and RB as part of step 2 (baseline design) of CERN's approval process
- U.S. CMS HL-LHC project documents this Science Flowdown in requirements spreadsheets in docDB
- QA procedures developed by iCMS subdetector managers, coordinated by iCMS TC, enforced by series of reviews
  - Part of step 3 (final design) of CERN's approval process
  - U.S. CMS HL-LHC L2s implement these QA procedures in their sub-project making sure also comply with U.S. project requisites *(details subject of T.J. Sarlina's and C. Wilkinson's talks)*.

Additional Material

iCMS to U.S. CMS Connections

- Overall coordination of the upgrades for the U.S. is through the Project Manager
- Overall coordination of the upgrades for CMS is through the CMS Upgrade Coordinator
- Connection between U. S. CMS **Subprojects** and International **subprojects** is at the L2/L3 manager level
  - The U.S. CMS L2 managers are members of the subproject Upgrade Management Board



Strong U.S. CMS roles in CMS governance

- The U.S. is embedded in all facets of leadership in international CMS
  - To name a few: Deputy Spokesperson, Physics Coordinator, Offline Coordinator, HL-LHC Upgrade Deputy Coordinator, Spokesperson Advisory Group, Collaboration Board Secretary, BRIL / HCAL / DAQ / MTD coordination
- Having this kind of leadership reflects our technical and managerial skills
  - It also means we share in all decision making, oversight, and technical interfaces
- Many of the scientists leading the U.S. CMS HL-LHC upgrades are also leaders in the international CMS organization
  - This ensures smooth communication between the U.S. project and the overall project