# Phase 1 Closing Remarks

Joel Butler

# Phase 1 definition

- Phase 1 has changed from its initial definition
- We have to view it as delayed but by an uncertain amount.
  - We have to guess the earliest date at which it needs to be ready and prepare for that
  - But we have to watch what really happens and delay decision making if there are possible big payoffs on new technologies that are on the verge of becoming real
- Some upgrades look like they ar far along; others less
  - In general, none is approved by CMS or funded for construction
- I would like to see the Phase 1 Upgrade “requirements driven”

# Operational Considerations for the Phase 1 Upgrade - 1

- ***Schedule uncertainties***
  - The uncertainties in the timing and length of shutdowns and when each threshold of instantaneous and integrated luminosity will be passed argue for a flexible and incremental upgrade strategy.
- ***Radiation Safety Issues***
  - Need to install upgrades in an activated device

# Operational Considerations for the Phase 1 Upgrade - 2

- ***Constraints to the Design of the Upgrades***
  - The key constraints on the individual detector upgrades are
    - each must be capable of being installed in one or two short shutdowns of 3 to 4 months, while leaving the experiment in a physics-ready/ physics-capable state at the end of each shutdown;
    - the risk of physical damage to the detector due to upgrade activity must be minimized;
    - the risk to the physics program through excess startup time for physics, compromised performance, or lack of integration with previously collected data must be minimized; and
    - radiation exposure and accident risk to people must be minimized.
  - One practical aspect of these requirements is that the upgraded detectors will have to use the same or very similar cables and piping to carry their services to those of the existing detector.

# Operational Considerations for the Phase 1 Upgrade - 3

- ***When the upgrades are ready to be installed, CMS will be a physics experiment in progress. Many important topics that CMS can address require large integrated luminosity that will be acquired over many runs. Since the data from many years will need to be combined in a consistent way, changes have to be introduced very carefully. The new detectors or electronics will be replacing well-understood devices, which even if they are beginning to degrade or show problems, may be participating in a discovery in progress. Under that circumstance, the new detector, in order to be inserted, must demonstrate***
  - ***that it is "physics-ready" and will take quality data quickly without a long period on commissioning, alignment and calibration with collisions that would result in lost data; and***
  - ***that the data from it can be combined seamlessly with data taken before it is installed***

# Operational Considerations for the Phase 1 Upgrade - 4

- Even then, if the experiment feels a discovery is imminent and that data from the next run are all that is needed, the collaboration might well be averse to changing parts of the detector or the electronics, especially those used in the trigger.
- A decision on the timing of the replacement of a detector or electronics is a matter for the management of the CMS experiment to decide based on an assessment of the gains from introducing a newer and more capable device vs the risk of physical damage to CMS during the opening and installation and the possibility of a protracted learning curve to integrate the new device.

# Operational Considerations for the Phase 1 Upgrade - 5

- This discussion above highlights the problems of making changes to an experiment in progress.
- Those problems can be addressed by adequate testing before insertion into CMS, by developing tested and efficient installation procedures, quick and reliable alignment and calibration techniques, and accurate cross calibration with the devices that are being replaced.
- To achieve these goals requires good design and in many cases special test stands and procedures.
  - We will need more system-level engineering than before
  - We may need test beam setups with substantial detector modules designed to cross calibrate replacement detectors against existing ones. The costs of equipment, facilities, and activities needed to accomplish this must be included in the project costs.

# Operational Considerations for the Phase 1 Upgrade - 6

- In the case of the off-detector trigger electronics, we will install new devices alongside the ones they are replacing.
- By sending the new devices a copy of the input signals, we can have both the new and the old system make trigger decisions and compare them to see if they get the same result.
  - Only when it is established that the new components get the same result as the original ones can the new devices be used in the experiment and the old devices removed. For all electronics, test and burn-in facilities will be needed.

# Operational Considerations for the Phase 1 Upgrade - 7

- Flexibility is a very important aspect of the planning for the upgrade.
  - Detector performance issues or even physics considerations may make it desirable to accelerate some upgrades.
  - Lower than expected luminosity may mean that detectors that will eventually suffer radiation damage will last somewhat longer and make it reasonable to delay the installation of their replacements.
  - The development of certain physics results may argue for an upgrade to be deferred until the discovery is pinned down with the existing configuration.
  - The lower than expected development of luminosity might argue in favor of installing something that would improve the efficiency of CMS or add a new capability that was not part of the original design.

# Conclusion

- Let’s move forward with all deliberate speed
- Let’s try to be requirements driven
- Let’s understand when it is worth waiting to make a decision that can affect the experiment for a decade