Beam delivery risk analysis

This is version with blanked out cost numbers, intended for posting on S4 meeting pages.

The first version of this analysis was put together as a table. After discussion, it was seen that more information is needed to be described, which makes the table format cumbersome to use. The plain text version is given below.

The assumed risk gradations are high (~50%), medium (~25%), low (~10%) and very low (~1%).

Risk: FD jitter

- Assumption in RDR / Initial Risk
  - Assumed that integrated design of IR and FD has adequate stability to be within the range of intratrain feedback for reliable collisions. Concern is that there are no similar SC magnets and available SC magnet vibration data are up to the micron range. The initial risk is estimated as high.
- Mitigation/detection in EDR
  - Studies of a prototype of similar technical design.
- Remaining probability of failure at the end of EDR & cost impact
  - After EDR studies, depending on the details of design and similarities to complete system, the risk may be reduced to medium. In case of failure, more complicated design may add XXM.
- Mitigation/detection in pre-construction
  - Continuation of detailed design and prototyping.
- Remaining probability of failure at the end of pre-construction
  - The risk remains medium, as detailed design brings new issues and risks that are being addressed.
- Mitigation/detection in construction & commissioning
  - The final design can give full answer, provided that stability of the field center can be measured with beam.
- Probability of failure in construction & commissioning & final cost impact
  - Remaining risk is estimated as low. In case of failure, mitigation may involve rebuilding the FD, with impact of XXM.

Risk: Beam halo

- Assumption in RDR / Initial Risk
  - Assumed that the amount of beam halo will be as predicted by simulations and the initially installed muon walls will be adequate for reducing the number of muons. The initial risk is estimated as medium.
- Mitigation/detection in EDR
  - Include large caverns for longer walls in the design. Simulation studies are not expected to give definitive answer on the halo.
- Remaining probability of failure at the end of EDR & cost impact

  - The risk remains medium. If longer walls are needed, the impact may be XXM.
- Mitigation/detection in pre-construction
  - No changes.
- Remaining probability of failure at the end of pre-construction
  - No changes.
- Mitigation/detection in construction & commissioning
  - Measure muon flux and if too high, either lengthen the walls or install doughnuts.
- Probability of failure in construction & commissioning & final cost impact
  - Remaining risk is estimated as medium, and in case of failure, mitigation cost is about XXM.

Risk: Prompt push-pull operation

- Assumption in RDR / Initial Risk
  - Assumed that push-pull operation can reliably be done in less than a week with the hardware and assumptions (IR hall of certain size and depth, etc) that is estimated and included into the cost. The initial risk is estimated as high.
- Mitigation/detection in EDR
  - Detailed engineering design.
- Remaining probability of failure at the end of EDR & cost impact
  - After EDR studies, the risk is expected to be reduced to medium. In case if a more sophisticated design and more costly hardware and solutions would need to be used to achieve desired goals, the impact may be to add XXM.
- Mitigation/detection in pre-construction
  - Continuation of detailed design.
- Remaining probability of failure at the end of pre-construction
  - The risk expected to be reduced to low.
- Mitigation/detection in construction & commissioning
  - Tests of actual hardware can be performed before start of ILC operation with beam, although the possibilities of significant design changes are minimal.
- Probability of failure in construction & commissioning & final cost impact
  - Remaining risk is estimated as low. In case of design failure, implementation of fixes may require XXXM, perhaps too costly to implement, and may just have to live with the achieved push-pull performance.

Risk: Beam dump performance

- Assumption in RDR / Initial Risk
  - Assumed that beam dump can perform as expected in the present design, with window surviving the beam density, shielding providing adequate conditions, water system providing adequate internal and external environmental conditions, and that the cost of decommissioning was not needed to be included. The initial risk is estimated as medium.
- Mitigation/detection in EDR

  - Engineering design and beam studies of a window prototype. May find that need to lengthen the extraction line to increase the beam size, include more shielding, and redesign the radiation water handling system.
- Remaining probability of failure at the end of EDR & cost impact
  - After EDR studies the risk may be reduced to low, provided that real site was considered. If not, it remains medium. If design changes would need to be done, the impact is XXM.
- Mitigation/detection in pre-construction
  - Engineering design for real site, continuation of detailed design and prototyping.
- Remaining probability of failure at the end of pre-construction
  - The risk reduced to low.
- Mitigation/detection in construction & commissioning
  - Further decreasing the risk.
- Probability of failure in construction & commissioning & final cost impact
  - Remaining risk is estimated as very low. In case of failure and the need of fixes, impact may be XXXM.

Risk: Laser wire diagnostics

- Assumption in RDR / Initial Risk
  - Assumed that diagnostics system can measure the beam with expected 1micron resolution laser wires for beam tuning. Concern is that such resolution was not achieved. The initial risk is estimated as high.
- Mitigation/detection in EDR
  - Studies of laser wire prototypes at PETRA and ATF2. Mitigation may involve lengthening the diagnostic section (~500m), to increase beam size at the laser wires.
- Remaining probability of failure at the end of EDR & cost impact
  - After EDR studies, the risk expected to be reduced to medium. If lengthening may be needed, impact may be to add XXM.
- Mitigation/detection in pre-construction
  - Continuation of detailed design and prototyping.
- Remaining probability of failure at the end of pre-construction
  - With continuing work, the risk is expected to decrease to low.
- Mitigation/detection in construction & commissioning
  - Final performance is studied with beam.
- Probability of failure in construction & commissioning & final cost impact
  - Remaining risk is estimated as low. In case of failure, mitigation may involve rebuilding the optics and lasers, with impact of XXM and the need to live with whatever performance achieved.

Risk: Collimation performance

- Assumption in RDR / Initial Risk

  - Assumed that Spoilers survive predicted number of bunches with the designed optics and beam size on spoilers. Also assumed that collimation wakes are manageable as in the assumed design (taking into account tail folding octupoles). Concern is that there are no reliable data on the edge of the damage, and that there is noticeable difference of theoretical and measured wakes. The initial risk is estimated as medium.
- Mitigation/detection in EDR
  - Measurements of collimation wakes and studies of collimation beam damage. Mitigation may involve lengthening the system (~500m) to increase the beam size at the spoilers or reducing the spoiler thickness and increasing the number of stages and again, length. May also have to open the IR and FD aperture, possibly vertex radius, possibly adding more intratrain feedbacks.
- Remaining probability of failure at the end of EDR & cost impact
  - After EDR studies, the risk expected to be reduced to low. In case of failure, and the need to implement redesigns, the impact can be XXM.
- Mitigation/detection in pre-construction
  - Continuation of detailed design and prototyping.
- Remaining probability of failure at the end of pre-construction
  - The risk remains low.
- Mitigation/detection in construction & commissioning
  - The integrated performance can be measured with beam.
- Probability of failure in construction & commissioning & final cost impact
  - Remaining risk is estimated as low. In case of failure, mitigation may involve rebuilding part of the system for XXM, and the need to have to live with whatever performance achieved.

Risk: Crab cavity system performance

- Assumption in RDR / Initial Risk
  - Assumed that crab cavity will perform (HOMs, phase stability) as expected, in the presently assumed design. Concern is that the phase stability and the level of decoupling are challenging. The initial risk is estimated as high.
- Mitigation/detection in EDR
  - Design, low power studies of a cavity prototype and two single cell tests of phase stability. Mitigation may involve the need to redesign part or entire crab cavity system, for example with 5 cells instead of 9, or 1.3GHz instead of 3.9GHz.
- Remaining probability of failure at the end of EDR & cost impact
  - After EDR studies, the risk may be reduced to medium. In case of failure, more complicated design may add XXM.
- Mitigation/detection in pre-construction
  - Continuation of integration and high power beam tests with two cavities.
- Remaining probability of failure at the end of pre-construction
  - With two cavity beam tests, the risk expected to be reduced to low.
- Mitigation/detection in construction & commissioning
  - The final performance will be studied.

- Probability of failure in construction & commissioning & final cost impact
  - Remaining risk is estimated as low. In case of failure, mitigation may involve rebuilding the system, with impact of XXM.

Risk: Fast feedback performance

- Assumption in RDR / Initial Risk
  - Assumed that the fast feedback can bring the beams into collisions as assumed in the simulations. Concern is that some effects, e.g. spray from secondary particles on BPMs, or other unknown, may affect its performance. The initial risk is estimated as moderate.
- Mitigation/detection in EDR
  - Studies of feedback prototypes at ATF2 and of performance of BPMs sprayed by secondary beam at ESA. Mitigation may involve changing location of feedback components.
- Remaining probability of failure at the end of EDR & cost impact
  - After EDR studies, the risk expected to be reduced to low. In case of failure, and the need of some redesign, the impact may be to add XXM.
- Mitigation/detection in pre-construction
  - Continuation of detailed design and further tests at ATF2.
- Remaining probability of failure at the end of pre-construction
  - The risk remains low.
- Mitigation/detection in construction & commissioning
  - The final performance will be studied.
- Probability of failure in construction & commissioning & final cost impact
  - Remaining risk is estimated as low. In case of failure, mitigation may involve rebuilding the system, with impact of XXM.

Risk: Energy and polarization diagnostics

- Assumption in RDR / Initial Risk
  - Assumed that energy spectrometers and polarimeters, upstream and downstream, can provide adequate and accurate diagnostics for the experiment. Concern is that the requested performance is beyond what was achieved. The initial risk is estimated as high.
- Mitigation/detection in EDR
  - Studies of prototypes of energy spectrometers at ESA and engineering design. Mitigation may mean including additional redundant systems or increasing complexity of design for present systems.
- Remaining probability of failure at the end of EDR & cost impact
  - After EDR studies, the risk expected to be reduced to medium. In case of failure, more complicated design may add XXM.
- Mitigation/detection in pre-construction
  - Continuation of detailed design and prototyping.

- Remaining probability of failure at the end of pre-construction
    - With further work the risk may be reduced to low.
- Mitigation/detection in construction & commissioning
    - The final performance will be studied.
- Probability of failure in construction & commissioning & final cost impact
    - Remaining risk is estimated as low. In case of failure, mitigation may involve rebuilding part of the system, with impact of XXM or having to live with what was achieved.

Risk: Final focus optics performance

- Assumption in RDR / Initial Risk
    - Assumed that final focus optics can be quickly tuned, diagnosed, aberrations minimized, and be ready for delivery of small time without the need of lengthy studies. Concern is that local chromatic correction was not used before and that tuning of the small beam was not routinely achieved. The initial risk is estimated as moderate.
- Mitigation/detection in EDR
    - Studies of beam tuning at ATF2. Mitigation may involve the need to include additional diagnostics or even significantly redesign the optics.
- Remaining probability of failure at the end of EDR & cost impact
    - After EDR, the ATF2 studies are expecting to reduce the risk to low. If additional diagnostics or big redesign would be needed, the impact may be to add XXXM.
- Mitigation/detection in pre-construction
    - Continuation of studies at ATF2.
- Remaining probability of failure at the end of pre-construction
    - With further studies, the risk may reduce to very low.
- Mitigation/detection in construction & commissioning
    - The final performance will be studied.
- Probability of failure in construction & commissioning & final cost impact
    - Remaining risk is estimated as very low. In case of failure, adding diagnostics may be XXM, and other large changes may be too costly to implement at this stage.

Risk: FD compactness

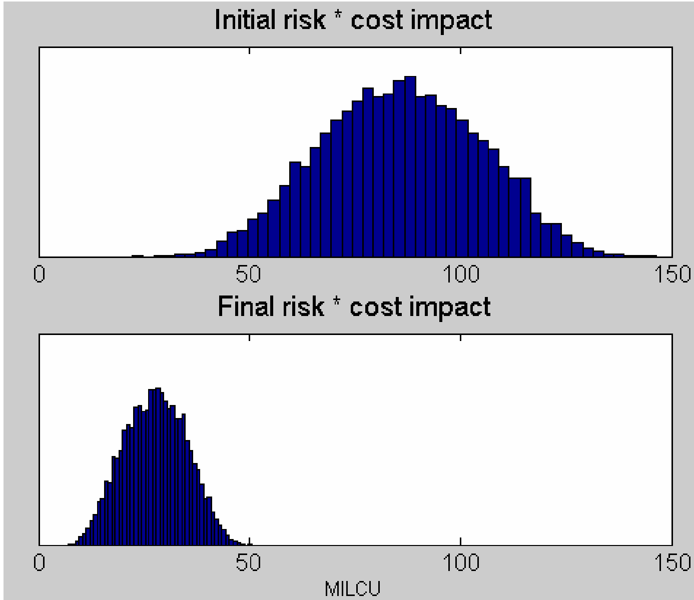
- Assumption in RDR / Initial Risk
    - Assumed that the FD can be designed with angle as small as 14mrad, providing two independent apertures at mere 49mm separation defined by 3.5m L* distance. Concern is that every mm counts in the design and technical details may be not considered yet. The initial risk is estimated as moderate.
- Mitigation/detection in EDR

  - Studies of a prototype of compact quad and engineering design. Mitigation may mean redesign to larger (e.g. 16mrad) angle, and possible modification of IR and forward region.
- Remaining probability of failure at the end of EDR & cost impact
  - After EDR studies, with integrated design and prototypes done, the risk expected to be reduced to low. In case of the need of redesign, the impact may be to add XXM.
- Mitigation/detection in pre-construction
  - Continuation of detailed design and prototyping.
- Remaining probability of failure at the end of pre-construction
  - With further work, the risk may be reduced to very low.
- Mitigation/detection in construction & commissioning
  - The final performance will be studied.
- Probability of failure in construction & commissioning & final cost impact
  - Remaining risk is estimated as very low. In case of failure, mitigation at this stage may involve downgrading the parameters, e.g. energy or rebuilding the FD, with impact of XXM.

Summarizing and evaluating the maximum impact on the cost, one can see that the **Initial risk * cost impact** is given by
(XX, XX, ...)
If this is added linearly (less likely), the **Initial risk*cost impact** is **XXXM**, if added randomly, the most likely impact is **XXM**.

The final risk * cost impact is correspondingly
(XX, XX, ...)
Again, if added linearly (less likely), the **Final risk*cost impact** is **XXM**, if added in randomly, the most likely impact is **XXM**.

Thus, the EDR and pre-construction efforts would reduce the BDS cost risk by a factor of three. As illustrated in the figure below.


Initial risk * cost impact
0
50
100
150
Final risk * cost impact
0
50
100
150
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