Remote Operations Workshop
Shelter Island, New York
September 17-20, 2002

Report on Working Group 3 Engineering Designs for Remote Operations

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Full Session Attendees: R. Bacher, DESY; H-J. Eckolt, DESY; D. Rice, Cornell; E. Siskind, NYCB Real Time Computing; K. White, JLAB; F. Willeke, DESY

GAN Working Group 3: Engineering Designs for Remote Operations

1. Introduction

The Charge of the Working Group was as follows:

- Examine in more detail the remote operation of accelerator hardware subsystems, in both commissioning and routine operations.
- Will presently designed hardware (for example, power supplies and klystrons) perform well enough with the experts not present on site?
- What additional design features need to be built in?
- What level of engineering expertise is necessary on site to assure effective operation of the facility?

The Working Group interpreted the Charge as biased toward the problem of a Global Accelerator Network (GAN) operated *and* supported machine. Although most of the discussion can be applied to any machine, some specific examples during discussions and presentations were drawn from ongoing designs related to Linear Collider (LC) machines.

To guide discussions, Working Group 3 developed a set of detailed questions addressing various aspects of the charge, which are found in *Appendix A*. It was not possible for lack of time to address all the questions posed, and some questions were raised that were not on the list. This brief report summarizes the main discussions and results.

2. Presentations

The following presentations were made in conjunction with the WG3 agenda. All may be found linked to the Remote Operations Workshop website:

Thoughts about Remote Operation in a Global Accelerator Network (GAN): Engineering Designs and Organizational Structures from the Engineer's and Operator's Point of View, Reinhard Bacher, DESY

Power Supplies for TESLA Test Facility 2, Hans-Joerg Eckoldt, DESY

Designing for Availability, R.S. Larsen, SLAC

Real Time Communications in Pulsed Accelerators, E. J. Siskind, NYCB Real Time Computing

Working Group 3 Summary Report, Powerpoint presentation, R.S. Larsen/ for WG3

3. Discussions

Because of time limitations it was not possible to cover all the questions posed in the above list. The WG concentrated on three main areas:

GAN Working Group 3: Engineering Designs for Remote Operations

3.1 Operations Engineering Model

Remote Control Rooms (RCRs); Operations & Maintenance on-site

Remote Control rooms were discussed in detail in other sessions. The purpose here was to envisage the maintenance models for a remote controlled site, the number and types of personnel necessary on site, and the access to experts for helping to solve systems problems. The presentation by Reinhard Bacher framed many of the relevant questions. Additional discussions in the WG3 Summary Report listed above expanded on the topic of types and locations of experts, and postulated the necessary organizational structure.

Post meeting, a block diagram was developed for both the Operations and Engineering models to illustrate the organizational concepts discussed in the summary talk. See Appendix B.

3.2 Design Engineering Models

Modular Design: This discussion focused on the need for Modular Design of all components for quick field substation of Field Replaceable Units (FRUs). H.J. Eckholdt's presentation of power supply design for TTF2 illustrated the concept of built-in redundancy. R. Larsen's presentation on Design for Availability gives examples of redundant quad power supplies and the redundant IGBT driver card solid-state modulator.

Standard instrument modules and electronics in tunnels were also discussed. Instrument modules and distributed systems such as vacuum tend to have considerable built-in redundancy, while heavy power equipment typically does not. Power RF systems achieve redundancy by building extra RF stations into the linac, so that there will be some spare capacity to keep the beam energy stable. In current linacs there is usually some headroom in the power systems, typically 2-3% redundancy. (Removed reference to LC.)

New Standard Modules: There is a need to develop a new standard instrument module to house instruments that will primarily communicate with one another and with higher nodes via high-speed serial links of copper or fiber optics. E. Siskind's presentation on Real Time Communications in Pulsed Accelerators describes the type of communications design that is necessary. The VME Standards Organization (VSO) is working on a standard design as mentioned in R. Larsen's WG3 summary talk. Assemblages of these modules have only a standard DC power input (e.g. 48V), internal DC-DC converters, analog or digital signal inputs and copper or fiber serial I/O. The parallel bus backplane, which currently pushes the limits of density and insertion forces (e.g. 3 row D sized VXI) and speed due to length and capacitive loading, essentially disappears. The equivalent connections are made on-board between chips with much shorter leads, and interconnected via high-speed serial copper or fiber. For accelerator instrumentation this structure has more than adequate bandwidth with current technology to collect and archive the data from every BPM on every beam bunch (Siskind).

Diagnostics was a frequent topic: How complete are the present diagnostics in reducing response and recovery time to a fault event, or even anticipating impending faults that could halt the machine; and how can additional diagnostics help? Various examples were discussed – DESY power supplies, SLAC Quad power supply and Solid State Modulator, etc. (H-J. Eckoldt, R.S. Larsen). Clearly additional diagnostics has a cost, but not necessarily a prohibitive cost, and the correct selection of cost-effective diagnostics should be examined case-by-case for all the major systems. Also the possibility of developing a standard diagnostics subassembly or chip that be implanted to gather information from inside system components, both power systems and instrument modules, should be investigated.

3.3 Systems Integration& Operations Support

Integration: Integration and commissioning manpower is frequently underestimated and many projects overrun in this area. The group made an effort to identify the various kinds of help needed, and how these people would interact with the maintenance and operations teams to which the systems are eventually handed off.

Documentation: Clearly the systems that are being transitioned into operations have to be documented especially well if the experts who have memorized the details are located long distances away. This also requires modern methods of archiving and retrieving those documents that are needed in the field in emergency situations, including remote access to the read-only archive and ability to rapidly locate and print out relevant documents.

Systems Maintenance: There is a need for a higher level of systems expert within the resident maintenance organization than in present models where systems experts are near at hand. These could be engineers, machine physicists or highly trained engineering/physics associates. A related challenge is to structure jobs for these people that include a mix of activities (including some long range projects) that are intellectually challenging.

3.4 Lines of Responsibility & Authority

A major concern in a diffuse organization is the maintenance of strong, clear lines of responsibility and authority. Traditionally the lines of authority flow upward to Operations and then to Operations Management, and then to higher levels of program and accelerator management. Establishing and maintaining such links will require extra levels of formal, written procedures that are frequently reviewed and are used in training, and a constant training effort at both the accelerator center and the Remote Control Centers. This model should be developed in parallel with any technical collaboration initiatives, and ways sought to test the management model along the way toward a full collaborative project.

4. Summary

4.1 Possible Collaborative Developments

The discussions suggest a number of possible collaboration developments. The following is a list of both technical studies and management modeling exercises.

4.1.1 *Availability Studies:* Development of availability models for all systems. Use common assumptions and availability criteria to build up the model for the complete machine. Develop a cost vs. Availability curve when including different levels of redundancy and diagnostics to reduce MTTR and improve Availability.

4.1.2 *Diagnostics:* Feasibility study of a standard imbedded diagnostics hardware and software with a serial interface to a suitable controller that can provide both local and remote information.

4.1.3 *Standard Instrument Modules:* Develop a module along lines of VSO initiative to support field instruments such as BPMs, Vacuum, Low Level RF etc. Develop standard software drivers and interface.

4.1.4 *Operations Engineering Support Model:* Develop requirements for Systems experts' duties to assist operations (a) at the site, and (b) as contacted through the Remote Control Rooms.

4.1.5 *Engineering Design and Commissioning Models:* Develop Requirements for Design experts' duties to perform Design and Commissioning as part of a Collaboration team.

4.1.6 *Documentation:* Develop Requirements and standards for (a) Design Documentation production, archiving and file sharing, and (b) Maintenance and Training Documentation, archiving and in-field retrieval.

Appendix A

Detailed Questions Relating to the Charge

The following questions were developed before the WG3 meeting to help identify topics. They were not intended to completely frame the ensuing discussions. The actual discussions were organized as time and interests of the participants permitted. Although they were not completely addressed, the original questions are repeated here for completeness of the record, and as reminders of areas that possibly could be developed in future discussions.

1) *TOPIC 1: Design Models*

   a) Charge: Will presently designed hardware (e.g. klystron, power supply *Subsystems*) work well enough with experts not present on site?

      Discussion Points

      i) Discuss Availability targets vs. current machine experience, factors in the Availability' equation. (Removed reference to LC.)
      ii) Which subsystems most affect Availability (e.g. RF sources, distribution, structures, cryogenics, power supplies, modulators)?
      iii) Can we make reliable performance extrapolations from present experience?
      iv) Examples of current problems where expert help is required in diagnosing *Sub-systems* (as opposed to Systems).
      v) Examples of current problems where expert help is required in diagnosing *Systems* consisting of interconnected Sub-Systems.
      vi) What new features in power component hardware design will minimize need for on-site experts?

   b) Charge: What new design features need to be built in?

      Discussion Points

      i) Subsystem Components
         (1) Problems of adapting hardware/firmware/controller designs to function smoothly through changes over 25-year life.
         (2) Modularity & Redundancy of current designs of major Sub-systems vs. required for Remote Operations. (Removed LC, repl.w/ Remote Operations)
         (3) Packaging standardization, rapid replacement of power components.
         (4) Packaging standardization, rapid replacement of new form factor instrument modules.
         (5) Appropriateness of 'Appliance' architecture for instruments, e.g. BPMs

(6) Potential development of radiation hard instruments on or near Beamline.
(7) Fiber optics limitations in radiation areas.
(8) Potential development of wireless data transfer in tunnels.

ii) Networks
(1) What are advantages vs. vulnerabilities of various architectures, protocols?
(2) What is bandwidth required for real-time response for beam stabilization & machine protection compared to current machines?
(3) Bandwidth required to archive data from *entire* Machine for off-line analysis.
(4) Real-time knobbing response.

iii) Machine Protection
(1) What new design features are needed to eliminate possibility of errant beams, if feasible?
(2) With what accuracy can we predict whether full power beams stored in damping rings are safe to inject?

iv) Personnel Safety
(1) Personnel safety relies on technical plus administrative controls. How well do current methods & need for on-site experts extrapolate to Remote Operations?

v) Diagnostics
(1) What *virtual tools*[1] for remote trouble-shooting can be imagined? How can we experiment with these?
(2) *What kinds* of additional diagnostics are needed in *which* Sub-System components to minimize need for on-site experts?
(3) What kinds of additional diagnostics are needed in *the overall accelerator Systems* to minimize need for on-site experts?
(4) What existing models will enable us to predict the *effectiveness* and *overall cost burden* of additional diagnostics?

2) *TOPIC 2: Commissioning Models*[2]

a) Charge: Examine in more detail the remote operations of Accelerator Subsystems during *Commissioning*.

Discussion Points

i) *Responsibility Model* for commissioning vis-à-vis design responsibility.

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[1] Mentioned in March 2002 Workshop: Scopes, transient recorders, control system test points in components, helmet-cam, world-wide pagers.

[2] In the March 2002 Meeting, Controls System Modes of Operation were defined as: 1) Accelerator component testing, 2) Commissioning, 3) Diagnosing problems, 4) Routine operations and5) Machine studies. Here we assume Commissioning includes the *Subsystem checkout* phase as well as the *Integrated System testing* phase, including 1)-3) above.

   ii) Which *Subsystems* require which types of experts during checkout?
   iii) Which *Subsystems* in the “typical” Machine are most challenging for experts?
   iv) During *Integrated System testing*, what additional functions require assistance of experts*?* What kinds of experts?
   v) Which *Integrated Systems* pose the most challenging technical requirements for on-site experts? How can the numbers be minimized?
   vi) Extrapolating from past experience, with what level of accuracy can we quantify these needs?

3) *TOPIC 3: Sustaining Engineering Models*[3]

   a) Charge: Examine in more detail the remote operation of accelerator Sub-systems during *Routine Operations.*

      i) What *Organizational Model* shall we use to evaluate the need for continuing support of Routine Operations?
      ii) What is the *Responsibility Model* for routine operations – e.g. in terms of manning shifts at a remote site, sending experts on-site to troubleshoot systems, sending experts to supervise complex on-site repairs of equipment that is too large to ship off-site?
      iii) What is the life-cycle model for electronics hardware? The Machine construction and commissioning time frame is longer than the lifetime of some commercial components. How does this affect how we design and implement in-house designs and how we specify purchased equipment?[4]
      iv) What *technical problems* for on-going support can be envisaged due to planned or unplanned changes in organization, loss of support from a collaborator etc?
      v) What additional *Facilities or Equipment* may be needed on-site in order to accommodate the international collaboration model of operational support?

[3] *Sustaining engineering* refers to two levels: Experts on site, and experts at ‘home base’ who consult as needed. An operations model will determine the mix.
[4] This could be a topic for a future GAN Workshop discussion.

Appendix B

A Conceptual Model for Engineering Development, Commissioning and Sustaining Engineering Support of Remote Operations and Maintenance

Some Post-Remote Operations Workshop Reflections

R.S. Larsen, SLAC
October 9, 2002

This section is included as the personal viewpoint of the WG3 Convener, as inspired largely by the Charge and the discussions of WG3. The author is indebted to the WG3 participants for their lively and stimulating discussions.

GAN Working Group 3: Engineering Designs for Remote Operations

1. Introduction

The task of the Engineering Designs for Remote Operations Working Group was to discuss the question of how technical "experts" would be used in a GAN remote operations model. For purposes of this discussion the assumed model is:

- Collaborating partners will agree to fund, design, build, commission and operate major systems of the machine. Funding of operations and support of specific contracted subsystems will continue into the indefinite future.
- Multiple control centers remote from the site will take turns operating the machine as an important part of the ownership model.
- Only the minimum number of experts will reside at the machine site, leading to questions of expert support requirements.
- Experimental detectors presumably will follow a similar model.

This note is intended not to summarize all the discussions of remote operation, but to open a serious discussion among design, engineering and operations experts of how the GAN model impacts the broad spectrum of engineering design and operational support requirements, which in turn dictates the technical and operational management structures that must be developed.

This question of structure must be answered clearly and agreement sought among collaborators before such a model can be brought into existence, before agreements of scope of technical participation can be struck among collaborators, and possibly before funding is possible. In other words, experiments can be contrived to show technically that remote operation of an accelerator is possible; but unless that experiment incorporates a realistic operational and technical support model along with a management structure defining both lines of authority and lines of responsibility, then it is extremely limited in evaluating the GAN concept. Such a demonstration is a more difficult experiment leading toward building a template for the real collaboration.

The full GAN model of a new machine must explore all aspects of designing, building, commissioning and operating a machine built through a co-equal partnership. The remainder of this note explores some features of technical, operations and support structures needed in a viable international collaboration that were originally discussed in the WG3 Shelter Island Workshop summary.

2. Controls Team Model

Figure 1 illustrates a controls management and operations concept. The accelerator site operates with a Maintenance Operations staff and a Safety Management staff. The Maintenance staff includes sub-groups specializing in each system, but also cross-trained on other systems. Each sub-group leader is specially trained as a *systems* maintenance expert. To obtain maximum machine Availability, *all* subsystems will be designed as far as possible to be modular with some level of redundancy for added reliability and for very quick replacement of a failed module. This applies especially to power systems, modulators, RF components and the critical support systems of low-level RF, timing and instrumentation.

Obviously these requirements must be factored into all conceptual designs as early as possible.

The Maintenance Operations group takes instructions from the current Remote Control Room (RCR) in charge. Optimizing operation of the RCRs will not be debated here; operations experts in consultation with the experimenters, machine physicists responsible for machine development and support staff will design this system. We assume that in the RCR the same functions are present as in any present control room, namely the equivalent of a Chief Operator, an on-duty Machine Physicist for machine development (MD) programs, and Accelerator Operators managing the various subsystems and operational modes of the machine.

When expert help is required, the Chief Operator or more senior person in charge if one is designated will place the call. A Systems Expert Coordinating Group with representatives from each RCR *a priori* will set up the shift coverage for on-call experts. More than one expert per shift should be available for any critical subsystem where subtle systems problems are likely to occur. These on-call experts can be located anywhere in the world, as long as they are within reach of reliable communications. The XNET Expert Network shown in the figure could minimally be a cell phone accessed from a guaranteed reliable link, but preferably the expert should have access to the web to view diagnostics and discuss the problem live with the Maintenance Operations person at on site. With wireless modems and laptops, this may be relatively easy to accomplish without requiring the expert to remain at a fixed location while on call.

A key question is how effective this support system can be in normal machine operations. Some present day operations models require the experts to be local and on-call at any time to come to the site when serious problems arise. This model will not work for GAN. Instead, one must assume that if a problem simply cannot be fixed over the remote linkage, one or more experts will need to hop an airplane to the site as quickly as possible. Thus both the accelerator site and the RCRs should be within easy reach of direct-flight air service. The total analysis of this problem again impacts machine design (e.g. redundancy and modularity) and maintenance models (e.g. ready spares for easily replaceable units or modules).

Above the “Protective Halo” of machine experts in Figure 1 is the overall Collaboration Operations Management group. This group is responsible for the smooth operation of the entire enterprise. It will develop metrics for the effectiveness of operations with the model shown, e.g. collect Reliability and Availability data for all systems and the machine as a whole, and make adjustments accordingly. Many problems will be related to inter-cultural communications and personnel management, and the problem of how to keep the remote Experts in close touch with the reality of an operating machine, the two really new components of a GAN versus a conventional system. Regarding the latter, the Experts will need to be involved in developing training materials and training maintenance people on an ongoing basis, and should expect to make site visits for these purposes. On-site workshops that bring the various team players together on a planned basis also will be necessary.

GAN remote control experiments should develop some version of this structural model as a test bed. A simple test of turning knobs in one remote location and operating a machine in another location is not much of a test. The test will be to actually solve problems with the remote experts isolated in a GAN-like fashion. This is not easy with present machine designs because they lack what can be called Design For Availability. However it may be possible to find an existing machine, or subsystem of a machine, that can serve as an experiment. The next requirement is to train the people in the remote location in operations enough to take over for at least a shift, with the remote Expert looking only at diagnostic information that can be obtained over the communications system.

3. Engineering Design Team Model

We now turn to the structure of a typical system design team based on the premise that there are clusters of experts for a given type of design at various laboratories and universities, and that a "final" model of a machine designed by international collaboration will attempt to involve the best people for a given discipline no matter what their affiliation. However, there is also an *ownership* model that requires the identification of a *lead laboratory* to develop each subsystem, and that match-up will depend on the machine technology and the laboratory's expertise. In some cases a laboratory can acquire the necessary expertise with the help of other experts in the collaboration. An example is the ongoing effort by Fermilab to manufacture X-Band RF structures, a field they were not actively engaged in, but which has been already shown to be feasible because of their general expertise in manufacturing. At present we have not made a basic technology selection between a warm and a cold machine, but irregardless we can experiment with an extended model for managing collaborative R&D of mutual interest.

Figure 2 shows a basic design engineering structure that approaches a GAN model. The model begins with small collaboration teams drawn from the different Collaborator-Laboratories where experts form a subsystem task team to advance the R&D in an area of common interest. One of the *"Collaboratories*" provides the person or persons who form the lead team, which means providing special leadership expertise and/ or resources. Other team members can be drawn from other laboratories whether or not they have the potential to carry a full system engineering responsibility in future. The determination should be made on the ability for the home institution to support the personal involvement as an immediate contribution and as an opportunity for a larger involvement in future.

These sorts of teams can be formed now, and some no doubt are already functioning that closely resemble this model. The important aspect is to make them operate efficiently as a project team. This requires a higher structure that operates like a project, where project-engineering disciplines are brought into the mix. This can only be done when designs transition from loose concepts to prototyping and development of a realistic set of requirements. *Figure 2* shows this transition as a dotted line to a higher stage of oversight when the R&D team becomes an Integrated Engineering Team for a particular system. When this occurs several related activities will be merged into the larger team as shown by the multiple arrows entering the Integrated Engineering organizational box. Above this box, the Project Engineering Management Team will specify formal Requirements for all elements of the subsystems and the System team(s) will fully transition to the project development phase.

4. Other Project phases

A Collaboration General Management Team sits at the top level. This team manages and coordinates the entire gamut of similar teams not only for the various technical elements, but for the full range of project activities: Conceptual design, development, manufacturing, installation, system integration, testing and commissioning. It will also oversee development of all structures for future operations as discussed in the model of Figure 1.

5. Discussion and Conclusion

This brief discussion is intended to begin a dialog of how technical, managerial and participation models can be constructed over the full range of tasks and activities needed for a machine built as a GAN type collaboration. Before we can claim an understanding of a machine that will support a GAN model these issues need to be faced as soon as possible. The expertise for answering these questions lies with experts representing the range of technical skills needed to manage, design, build, commission and operate a next-generation accelerator. Moreover, the Availability goals for such a machine have not been clearly addressed and many technical questions of Design for Availability have not been answered. These issues affect the design specifications, the maintainability of the final product, its cost and the way in which it will be maintained. It seems crucial to begin modeling the subsystems and systems design models as soon as possible, along with the operations model. If we enter into a situation where funding is actually approved without these areas being sorted out ahead of time, and factored into the proposal, we can guarantee nasty surprises and cost overruns and other forms of management chaos. Judging from recent history, ignoring these issues indeed could lead to a major disaster.

From just an Operations point of view, several issues loom large: The training of remote operations groups to a high level of competence and trustworthiness; achieving efficient handoff from one group to the next; training the on-site maintenance staff to be able to independently handle a larger range of systems and subsystems issues; and finally the difficulties associated with making remote expert help almost as effective as with the person present physically. Technology, better documentation, and reliance on developing Expert Systems can help with some of these issues, but much design and experimentation is necessary before it can be accurately evaluated.

Grappling with these issues now will force the community to begin the give-and-take necessary to identify the issues of designing and building a functioning shared-ownership Collaboration team. This needs to be done before any more collaborator-competitors drive any more stakes into the ground. When non-negotiable conditions become fixed in the minds of the major proponents, forming a true shared partnership and shared ownership collaboration where all parties are satisfactorily included becomes intractable both in principle and in practice.

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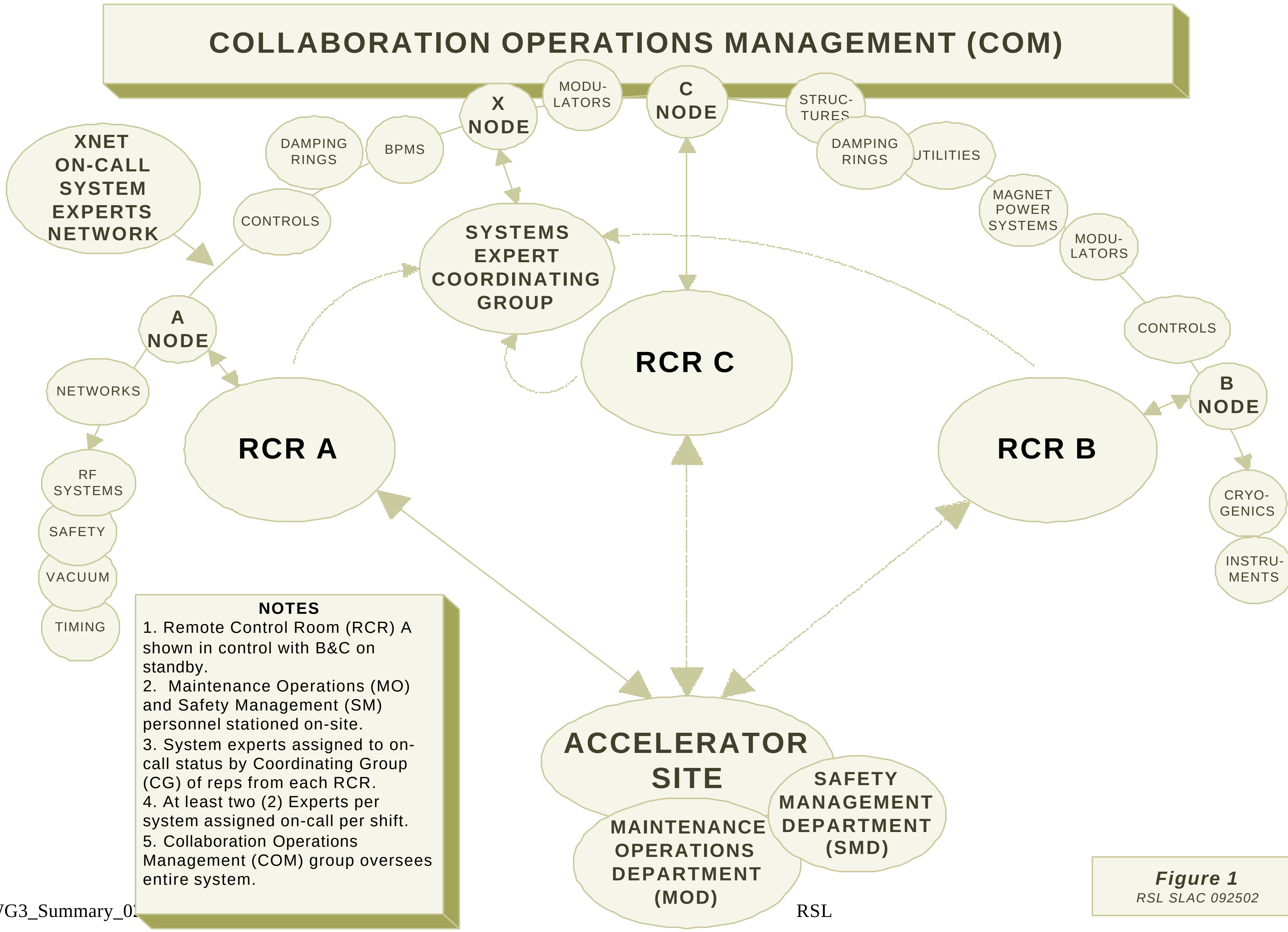

Figure 1
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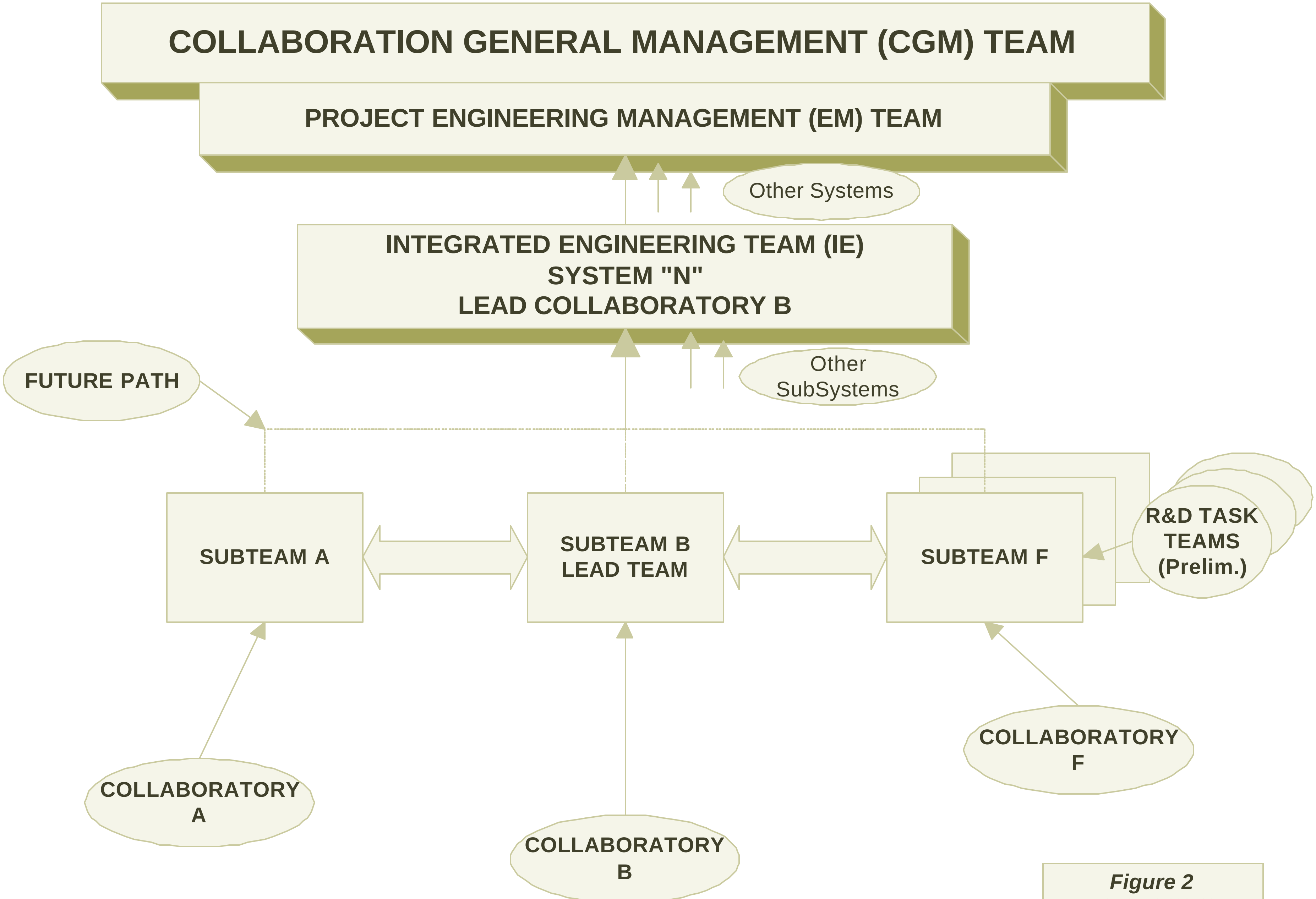

Figure 2
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