Site Characterization and Foundation for Dismantlement of the Yongbyon Nuclear Facility in the DPRK

A Proprietary Proposal from the Texas Tech University Center for Environmental Radiation Studies

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A site characterization and dismantlement planning program will be developed and implemented at the Yongbyon nuclear facility in the Democratic People's Republic of Korea (DPRK).

The proposed program will be based on (a) science diplomacy with an international team approach and (b) conventional international standards so that the project results in credible, scientifically valid data that can be used for planning the dismantlement phase.

The proposed program will become a platform for (a) engaging North Korean nuclear scientists, engineers, and technical personnel, (b) guiding DPRK nuclear experts into the international community and international standards, and (c) establishing the foundation for a radiation workers safety program for the DPRK.

The proposed program will contribute to United States nonproliferation, threat reduction goals by providing a growth path for professional employment of North Korean nuclear experts in peaceful endeavors and bringing them into the international community.

The proposed program will create and implement a radiation worker's safety plan and will provide training, planning, feasible scheduling, and documentation that will result in the dismantlement of the Yongbyon nuclear facility.

Introduction and Background

The Yongbyon nuclear facility was the cornerstone of the nuclear weapons program of the Democratic People's Republic of Korea (DPRK). As a consequence of the Six-Party talks, the DPRK agreed to disable the two Yongbyon reactors (5 and 50 MWe) and disclose historical details of their nuclear weapons program. Reportedly, disablement has begun and inspectors from the International Atomic Energy Agency (IAEA) have been invited to return to the DPRK. The symbolic public destruction of the main cooling tower occurred on 27 June 2008.

The present proposal addresses the basic problem of how the Yongbyon facility might be dismantled and how the United States might lead the process needed to achieve such a goal within the context of nonproliferation and personnel redirection.

In the United States and Europe, decommissioning, dismantlement, and disposal projects are highly proscribed and regulated. For example, the U. S. Government document (Environmental Protection Agency) entitled, *Multi-agency Radiation Survey and Site Investigation Manual* (known as MARSSIM) serves internationally as the most widely-accepted set of guidelines. Under these circumstances the entire process is strictly controlled and highly predictable regardless of technical complexity. Unfortunately, however, the United States-European model is not directly applicable to the challenge presented by the Yongbyon facility. Although useful, the MARSSIM guide would need to be simplified and modified to account for the likely situation at Yongbyon.

International tension over the DPRK's nuclear weapons program, isolation of the regime from the international community, virtual absence of technical collaborations, suspicion of the outside world, secrecy, historical factors on the Korean Peninsula, and lack of credibility with the IAEA, are just some of the reasons why a creative strategy is required for the Yongbyon facility. Here we propose such a strategy based on our ongoing experience with site characterization, radiation worker safety, dismantlement, and personnel redirection in a nonproliferation context at the Al-Tuwaitha Nuclear Research Center in Iraq. The challenge presented in Iraq is similar, but obviously not identical, to the challenge presented by the Yongbyon facility in the DPRK. More important, however, Iraq is the only available analog to Yongbyon. For this reason it is essential to look at the strengths and weaknesses of our Iraq program. Lessons learned from the strategy we have employed in Iraq have applicability to the Yongbyon program.

Dismantlement of the Yongbyon nuclear facility will be a complex task because the facility is very large and the buildings and site area have not been characterized in terms of contamination. Moreover, dismantlement of contaminated buildings with thick cement walls or metallic barriers—such as the reactors and laboratories at the Yongbyon facility—is a challenging proposition under the best of conditions. But when Yongbyon is viewed in context of decades of conflict, technological isolation from the Western World, social deprivation, and nonproliferation goals, dismantlement of the facility is a

daunting but important task that offers a unique opportunity to engage technical experts through scientific diplomacy.

As we envision it, our program for Yongbyon site characterization and dismantlement accounts for the complexities that we anticipate. Our proposed program also accounts for basic United States goals in the areas of nonproliferation and threat reduction. Although nonproliferation goals could be viewed as an added complexity to the challenges of nuclear facility site characterization and dismantlement, our proposed program, based on our experiences in Iraq, incorporates redirection through engagement. Our strategy involves guiding North Korean scientific and engineering experts through the entire process of site characterization, radiation worker safety, and planning and preparation for facility dismantlement. As we have done in Iraq, we propose to introduce the North Korean specialists to the international community and international standards.

The program that we propose makes several assumptions. One of these assumptions is that we will be able to gain official access to the Yongbyon facility. Whether this will require a special agreement between the United States and the DPRK, or sanctioning through the Six-Party talks is unknown to us at the present time. Another assumption is that we will be able to assemble and mobilize an international team including qualified laboratories and scientists in Russia, Ukraine, and South Korea and faculty from the new University of Science and Technology in the DPRK. We are confident that an international team is essential and that it can be assembled based on our experience with foreign laboratories. Our lengthy (10 year) relationship with the International Radioecology Laboratory (IRL) in Ukraine is one example. The IRL is an active partner in our Iraq program, participates in the IAEA technical meetings on Iraq, and, most important, the IRL has had contacts with the North Koreans as recently as January 2008. For all of these reasons, we believe the IRL can play a pivotal role in our proposed Yongbyon program. Finally, we also assume that if the scope of the program allows it, we will be able to partner with other laboratories in the United States.

As planned, our program will last two years and cost $ 5.9 million dollars. Program management will be located at the Texas Tech University Center for Environmental Radiation Studies. At the end of the two year time-frame there will be (a) credible site characterization data for the Yongbyon Nuclear Facility, (b) a functional personnel redirection program, (c) a Radiation Worker's Safety Program, and (d) a basic planning document for dismantlement.

Basics of Site Characterization and Dismantlement

The proposed program describes a site characterization and dismantlement planning process for the Yongbyon nuclear facility in the DPRK. Site characterization is a prerequisite for safe dismantlement and disposal of materials from a nuclear facility. Site characterization serves as the basic guide to project planning and management. It also provides a 'before' understanding of the situation in the vicinity of the facility and is the foundation for environmental remediation. An understanding of the distribution and type(s) of radionuclide contamination also is a prerequisite to planning the physical aspects of dismantlement, which could increase, scatter, or otherwise spread contamination. Site characterization data and analysis thus provide the key information needed in order to plan for protection of local area and regional public health and the practical aspects of radiation worker safety. Finally, nuclear facility site characterization is a necessary first step for environmental remediation following the dismantlement process.

Ideally, a nuclear facility site characterization produces a geospatially-based understanding of radionuclide levels and distribution across a landscape. The scope and level of detail in such an analysis is determined by a combination of factors. The lead factor is the historical (prior) use of the nuclear facility and the type, number, and spatial distribution of physical structures. The local environmental and landscape features including water table, habitat types and their distributions, public access, area or regional land use, and soil types(s) are other important factors that define the strategic plan for a site characterization program.

Chronologically, nuclear facility site characterization begins before physical dismantlement of buildings, reactors, and fixed equipment. But at the same time, the characterization strategy must be consistent with the objective of dismantlement. This means that the groundwork for dismantlement is concomitant with site characterization. Moreover, dismantlement of selected objects can begin while site characterization activities are continuing in other areas of the nuclear site. Dismantlement of large nuclear facilities requires extensive preparation. If it is integrated with site characterization, it is (a) practical to organize the dismantlement process into manageable phases, (b) select 'easy' dismantlement projects for practice, and (c) reduce site characterization time and effort by tailoring to the practical needs of the dismantlement group.

It is inevitable that nuclear facilities and their use in any country will attract public attention. Much of the public interest in such facilities is international and well-organized. Consequently, although nuclear facilities might not attract public attention within the country where they are located—especially in countries with repressive governments—there still will be international public attention. Public attention typically is global and can be expected to have ideological foundations. As a result of the foregoing factors, scientific credibility ('believability') is the essential cornerstone for nuclear site characterization.

The TTU Iraq Program and its Application to a Strategy for Yongbyon

The Texas Tech University team from the Center for Environmental Radiation Studies has more than 15 years of experience conducting research, training, and characterizing nuclear facilities and their immediate environments, and dismantlement planning at Chernobyl, Ukraine and Al-Tuwaitha Nuclear Research Center in Iraq. All of the individual projects within this overall program have included engagement and redirection aspects of nonproliferation. Funding has come from multiple sources, including the United States Department of State, Department of Energy, Texas Excellence Funds, the United States Civilian Research and Development Foundation, and the United Kingdom Ministry of Finance and Industry. We believe that our recent and ongoing program in Iraq, which involves the Ministry of Science and Technology, the Ministry of Environment, and the Department of State weapons personnel redirection program in Baghdad, is relevant to the present proposal and for that reason it is discussed in this section.

In Iraq, the Al-Tuwaitha facility is the main nuclear complex. Located about 18 km south of Baghdad, the Al-Tuwaitha facility is a massive complex with more than a hundred buildings enclosed by a 100-meter high earthen wall. Under the previous regime the facility was managed by the Iraq Atomic Energy Commission (IAEC). The role of Al-Tuwaitha was to support Saddam's nuclear weapons program. Uranium enrichment and production of plutonium and polonium are three examples of weapon-relevant activities that occurred at Al-Tuwaitha prior to 1991. The complex includes waste processing buildings, radiochemistry and other laboratories with hot cells, buried liquid waste tanks, and three badly damaged reactors. Under the best of circumstances the Al-Tuwaitha nuclear facility would present a complex engineering and regulatory challenge with little similarity to the typical decommissioning project for former nuclear power plants. Under the actual circumstances in Iraq, which include a lack of regulations and regulators, uncertain regulatory authority, inexperienced managerial and planning personnel, sporadic electrical supply, irregular access to contractors and heavy equipment, and the threat of attack by insurgents or terrorists, the dismantlement of facilities are a daunting task.

Our involvement with Iraq began in 2003 and includes experience with nonproliferation issues, participation in the creation of the original Iraq Radioactive Source Regulatory Authority (IRSRA; CPA Order 72), and development and implementation of the weapons personnel redirection program (a State Department Program represented in Baghdad by the Iraq International Center for Science and Industry). Our strategic approach to the Al-Tuwaitha nuclear facility was developed in 2005 and began with a facility site characterization study that involved fieldwork, engagement of Iraqi personnel through the redirection program, purchase of laboratory equipment and provision of training to enable Iraqi collaboration in the public health

aspects of the work, and initiation of a public health assessment project in the immediate vicinity of the Al-Tuwaitha nuclear facility.

Iraqi laboratories at the Ministry of Science and Technology were unable to analyze the 400 environmental samples that we obtained during our fieldwork in 2005. This is an important point with application to the Yongbyon facility in DPRK. First, there in fact were some Iraqis—former Saddam propagandists—who delayed the project by incorrectly insisting that they could and should do the analysis. In the case of Yongbyon we anticipate similar road-blocks will occur, even after we have achieved working agreements with administrative personnel. Second, because Iraq had no analytical credibility with the IAEA any data produced by them would be suspect. At the same time Iraqi credibility in the international community ultimately would be essential to the entire dismantlement process. Third, development of a laboratory capability, training of personnel, and quality control testing through the IAEA would take at least several years and more than a million dollars (USD) to accomplish. Our solution was to engage the International Radioecology Laboratory (IRL) in Slavutych, Ukraine. By bringing the IRL into our program, we linked a facility created by the United States under the Department of Energy nonproliferation/personnel redirection programs in the former Soviet Union with the Department of State nonproliferation/personnel redirection program in Iraq. Because the IRL had successfully passed IAEA quality assurance tests, any analyses conducted there would be scientifically valid and credible. Additionally, the well-equipped IRL became a training base so that Iraqis in the Department of State redirection program could travel there for participatory training in radiochemistry. Because such training included an opportunity to analyze samples brought to the IRL from the Iraq nuclear facility, the Iraqi trainees developed a sense of stake-holding in the site characterization program. Stake-holding significantly enhances the engagement experience.

We anticipate that the Yongbyon nuclear facility and the DPRK personnel skills will present a situation similar to what we encountered early in our Iraq program. Although we have not had an opportunity to visit DPRK labs, we expect that data analyses conducted by them will be viewed with skepticism for many of the same reasons as was data generated by Iraqis. One lesson from the dismantlement project in Iraq is that isolation from the world community—a characteristic of dictatorship—destroys credibility, creates a cultural and psychological barrier to joint work, and hinders collaboration because of a technology gap. Our experience with the legacy of Saddam's dictatorship in Iraq was a very important consideration in developing our proposed strategy for Yongbyon. We are convinced that shared stake-holding with the North Koreans is essential for successful engagement and redirection. It also is essential to the entire process of site characterization, radiation worker safety, and eventual dismantlement. But in order to achieve shared stake-holding it will be necessary to overcome the legacy of dictatorship, which produces a 'paradigm' of conducting science and engineering in a secretive, isolated world.

The legacy paradigm of dictatorships has both individual and organizational components. It also can be confused with 'culture,' so it is important to understand that

culture (as the term is used in anthropology) and our idea of a legacy paradigm are not the same. Based on our own experiences with weapons personnel redirection programs in the former Soviet Union and in Iraq, their respective scientific and engineering legacy paradigms have a broad overlap, whereas their respective cultures do not. In organizational terms, a dictator's legacy is significant and difficult to overcome. Under a dictatorship organizations tend to be highly compartmentalized ('stove-piped), workers tend to stay within well-defined assignments, data are manipulated to match expectations and generally inaccessible, and in a hierarchical sense decision making power is concentrated at the top. All of these features were challenges in our Iraq nuclear facilities program. And all of these features can be expected at Yongbyon where they will be undesirable to site characterization and dismantlement planning and implementation.

Based on our experience with Iraq, and Saddam's legacy, we have developed a specific training philosophy, which we will apply to the DPRK personnel. The basic elements are as follows: technology must be appropriate to working environment at Yongbyon; lines of authority and responsibility must not be diluted and organizational processes must be emphasized; conceptual training must proceed 'engagement;' the legacy paradigm must be factored into training; internationally-accepted principles override cultural differences; and train the trainers is the most efficient way to insure continuity and growth of the work force.

Typically, nuclear facility decommissioning and dismantlement begins with a scoping survey and site characterization study for the facility. In Iraq we completed the collaborative site characterization study at Al-Tuwaitha before we pursued the foundation work for dismantlement. At Yongbyon we propose to integrate these activities because ultimately each affects the direction and purpose of the other. We also propose to lay the foundation for a Radiation Worker's Safety Program (and eventually a health physics program) concomitantly with planning for dismantlement. From our experience in Iraq, however, we anticipate that both the planning for dismantlement and the Radiation Worker's Safety Program will present special challenges.

For the Al-Tuwaitha nuclear facility dismantlement, an Iraqi delegation from the Ministry of Science and Technology developed the first plans, which included their risk assessments and a priority list for dismantlement. These plans were presented to IAEA technical meetings in Vienna between 2006 and 2008. Delegates attending the meetings commented and made suggestions and representatives from a United States national laboratory advised the Iraqis. But for reasons discussed above, this overall process had limited impact. Although the Iraqi delegation to the IAEA eventually produced a document that looked like—mimicked—a typical United States or European dismantlement planning document, it was clear that they would be unable to actually implement it. This is an important point that undoubtedly applies to the DPRK.

Superficial engagement might be satisfactory in some instances, but mimicking complex planning documents is unsatisfactory if those documents are intended for actual implementation in nuclear facility dismantlement. To work around this problem we introduced a Train & Engage Program that was funded by the UK Ministry of Finance

and Industry (which includes a Nonproliferation Program). The IRL in Ukraine served as the Train & Engage venue. At the IRL we introduced a team of private sector US experts who mentored the Iraqi team and worked with them to create a planning process that (a) was tailored to their particular needs, (b) consistent with international principles, and (c) realistic in terms of the financial and political situation in Iraq.

Cultural differences and historical realities clearly affect the ways that people plan projects and visualize outcomes. Mimicking will not overcome this problem; instead mimicking results in impossible expectations followed by frustration followed by a reversion to previous ways of doing business (the legacy paradigm). Overall, our Train & Engage Program was successful because (a) it involved an extensive workshop on how to think through the planning process for site characterization and dismantlement and (b) was based on principles that transcend culture and legacy. As part of the program, the US-Ukraine-Iraqi team also conducted a novel project together in the abandoned, contaminated, city of Pripyat, Ukraine (about 2 km from Reactor IV, which is the one that exploded in 1986). Our idea was to use this project as 'neutral' ground where everyone in the combined team has assigned tasks ranging from management and planning to scheduling and databases to site characterization to regulation. Our Train & Engage Program concept has broad utility and we will apply it to our engagement/training program for DPRK management and technical personnel.

The Yongbyon Program that we propose is based on two fundamental positions: (a) the program requires an international team and (b) engagement with the DPRK personnel must be balanced and truly collaborative. At the outset we plan to include the International Radioecology Laboratory in Ukraine. Our selection of the IRL is based on the fact that this laboratory is recognized by the IAEA, has contributed significantly to the Iraq nuclear facility program, is an investment of US nonproliferation funding, and provides access to Pripyat as a training ground. But another reason is because the DPRK nuclear services organizations contacted the IRL in regard to possible future training as recently as January 2008. This contact was made independently from the program being proposed by us, but the dialog between the Director of the IRL and the DPRK illustrates that we already have a starting point for development of an international approach to the North Koreans. In addition to the IRL, we plan to involve a Russian laboratory in St. Petersburg, the Nuclear Human Resource Development Center of the Korea Atomic Energy Research Institute (Republic of Korea), and the new University of Science and Technology in DPRK. We also are mindful of the recent meetings between North and South Korean scientists and the idea of an "Inter-Korean Science Center" (reported in *Science*, 2006, 11 April) and we will incorporate our project within the context of ongoing scientific exchanges.

Program Management

The proposed program will be housed at the Center for Environmental Radiation Studies at Texas Tech University in Lubbock, Texas. The Center presently occupies space in the GIS-Bioinformatics wing of the Experimental Sciences building. Financial management and accounting for Center projects is either handled directly by the Center's Administrative Assistant or through the Department of Biological Sciences, which is the academic home for the Center and most of the faculty associated with it. Like other major research universities, Texas Tech University has an independent Research Services office that handles grants and contracts.

Leadership and reporting for the proposed program will be supplied by the two co-investigators, Drs. Carleton J. Phillips and Ronald K. Chesser (who also is Director of the Center for Environmental Radiation Studies). We are directly supported by an Administrative Assistant with an office next to our offices in the GIS-Bioinformatics wing and by the 13-person professional staff (including accountants and purchasing personnel) in the Department of Biological Sciences, located nearby. Our Iraq program also has been supported by other faculty members (one from Biological Sciences and two from the Texas Tech University Institute for Human and Environmental Health and Department of Environmental Toxicology) and three graduate students (Ph.D. candidates).

Programmatic Plan

The proposed program work plan is presented in detail in the following section of our proposal. In the overview we envision that it will unfold in a series of logical steps. We anticipate that the program will need adjustments as it goes forward. Indeed, based on our successful experience in Iraq we expect that intangibles such confidence building and developing collaborative relationships will affect our intended work schedule.

The proposed program is for two (2) years, with the intention of renewal. We intend to use the first year to (a) create the appropriate working relationships, (b) create an international support team, and (c) begin nuclear facility site characterization. The second will include training, continuing site characterization, and the planning phase for dismantlement. Ideally, in the second year the DPRK will have requested IAEA technical assistance.

Our initial visit(s) to the DPRK probably will be diplomatic-style visits, which will consist mostly of meeting and discussing our goals and objectives with appropriate officials. For our work in Iraq and in other countries in connection with nonproliferation programs, we anticipate that a series of discussions and perhaps even more than one trip will be required for us to shift from meetings with administrators to meetings with scientists, engineers, and other specialists capable of collaboration. In this process, which we call 'science diplomacy,' the main goal is to establish a rapport with colleagues who

have scientific interests in common with our own. We understand, of course, that internal politics, competition within the DPRK community, suspicion of the outside world, and a penchant for secretiveness will be obstacles to progress. We also understand that lack of experience with the working habits, expectations, and ethics of American academic scientists are some of the other issues that we will encounter. But here again our experience in Iraq and several other countries will be valuable. As we develop our working relationship and 'plans' with DPRK colleagues, it also will be helpful for us to achieve a scoping study of the Yongbyon nuclear facility. The sooner that we are able to visit the facility and obtain data in tandem with the North Koreans, the sooner we will gain a sense of progress toward site characterization.

Development of our international team will follow our initial planning visits to the DPRK and the Yongbyon nuclear facility. Our plan is to host a meeting of the entire team at a location acceptable to the DPRK. We think that this team meeting will be the ideal place to develop the overall plan for formal site characterization and planning for dismantlement. Such a plan will serve as the framework for all activities in the second year of the program and will be particularly important in terms of both training and redirection activities.

In the second year of the program we will focus on creation of the Radiation Worker's Safety Program and, especially, on the planning for dismantlement. It is important to appreciate that dismantlement is a very complex process. We anticipate that the planning and scheduling process will require extensive analysis, site visits, and analyzed data from site characterization work.

Work Plan

Phases of Work

Characterization of the Yongbyon Nuclear Facility should be conducted in four distinct phases of work (see Figs. 1 and 2):

- Phase I – Science Diplomacy and International Team-Building Phase
- Phase II – International Team Coordination and Training Phase
- Phase III – Site and Facility Characterization Phase
- Phase IV – Analysis and Reporting Phase

The separation of schedules is a necessary element of the work because of uncertainties in the working environment at Yongbyon, the need to establish administrative, scientific, and collaborative contacts in the DPRK prior to commitment to large-scale deployment of personnel and equipment, the need to employ adequate safety assurances and training prior to field work, to scale the field teams and equipment to the level of available life support at the site, and to establish mutually agreed upon work plans and schedules to accomplish the site characterization. All phases of the work include DPRK collaborators and it is expected that DPRK will designate a Program Manager, Project Planners, Team Leaders, Regulators, as well as field and laboratory analysis teams for this task.

Phase I – Science Diplomacy and International Team-Building Phase

The first phase of work involves a preliminary visit of principal investigators to the Yongbyon Nuclear Facility to assess logistical support at the site, establish key DPRK contacts that will facilitate the assessments, determine access to the sites, and evaluate local laboratory capabilities and protocols. This logistical planning phase enables face-to-face discussions between the USA and DPRK administrators and scientists responsible for overseeing the cooperative efforts for site and facility characterization at Yongbyon. It is also anticipated that field assistants and analysts from DPRK would be assigned to help conduct preliminary field work. The USA team would seek to make contacts at the newly created University of Science and Technology in DPRK to buttress scientific collaboration. It is likely that initial contacts will be primarily administrative rather than technical/scientific personnel. For this reason, we foresee that a second visit will be necessary to assemble DPRK technical collaborators who will facilitate the field and laboratory portions of the project.

Subsequent to agreements on the initial scope of work and access to the Yongbyon field sites, a second visit by USA personnel will be required to assess the working environment for site and facility characterization. An important activity during Phase I will be to conduct a broad scoping survey in the areas to be sampled. A scoping survey is a general evaluation of effective dose rates, selected soil/water sampling, and swab readings from discarded scrap and equipment in the areas of interest. The survey is not intended to replace a comprehensive site characterization, yet it should be sufficient to provide a general understanding of the prospective work sites. Results from the scoping survey will assist the assessment team and DPRK collaborators to: 1) determine the radiation dose environment and potential hazards and safety concerns in which the

characterizations will take place. The dose rates as well as radionuclide activities will be used to address personnel protective equipment requirements, safety training requirements, and work time limits for the areas; 2) estimate the geographic and numerical scope of the required sampling regime; 3) determine the number assistants required for field work and level of training needed for collaborative personnel; 4) assess on-site laboratory capabilities and response times; 5) evaluate the skill levels and work ethics of DPRK field assistants and laboratory personnel; 6) provide insights for the feasibility of ultimate site objectives, including unrestricted use, restricted use, mixed use. These data will permit preliminary discussions regarding remediation options together with the financial commitments needed to meet each objective; and, importantly, 7) ensure that field teams have access to the sites required for a complete environmental characterization. A facility will be identified in which exercises for conducting a facility characterization can be carried out. Ideally, this facility would be one of high priority on the USA list for ultimate dismantlement. If this is not feasible at this time, then a closed or limited-use facility would suffice. The facility may or may not contain radioactive contamination, but one with some contamination would be preferred. Once a facility is decided upon, the team should obtain as-built schematics of the building spaces in order to plan future characterizing activities. Discussions with local authorities would be conducted to build a record of historical uses (especially those that may lead to radionuclide contamination) in various areas of the building.

Subsequent to the scoping survey and analyses, the principal investigators from the USA and DPRK will be able to formulate work plans, timetables, and logistical support requirements for the site characterization at Yongbyon. The work plans will include details for sampling protocols, numbers and types of samples, analytical procedures, transportation, and export of samples for additional analyses in foreign cooperative laboratories. DPRK administrators and USA investigators will propose an agreement regarding travel of DPRK collaborators to foreign cooperative laboratories subsequent to the upcoming characterization work (Phase III). Personnel should be identified for the following categories: Program Manager (1 or 2 persons); Project Planner (1 person); Field Survey Team (1 leader and 6 – 12 members); Laboratory Analysis Team (1 leader, 5 – 10 members); Database Team (1 leader, 4-8 members); Regulator (1 – 3). Care should be taken to select trainees that will have the authority and responsibility for implementing the next phases of work. This will prevent the potential problem of "dilution" of training by having untrained authorities counteracting the decisions of knowledgeable personnel. This list of initial trainees/collaborators will provide us with contacts for organizing our next phases of work at Yongbyon. The list of personnel will be supplemented in later work. Methods for transport of subsamples out of the DPRK to cooperating laboratories will be agreed upon. A portion of all samples taken (except for swabs) will remain in the DPRK. Plans will be made for key DPRK collaborators to join the larger USA-led team for the next phase of work.

Phase II – International Team Coordination and Training Phase

The second phase of work on site characterization will be to assemble an international team of experts to conduct work at Yongbyon and sponsor a workshop focused on detailing work plans for all teams. The composition and location of the cooperating teams can not be determined until the scoping survey data are complete and agreements have been reached on the scope of work at the site. After the labs have been identified there will be an international team meeting held to discuss lab and personnel responsibilities as well as equipment needs and financial arrangements. If DPRK

personnel are unable to travel out of the DPRK, then we will arrange to conduct the team meeting at or near the Yongbyon site.

Figure 1. Work sequence for site & facility characterization at Yongbyon Nuclear Facility.

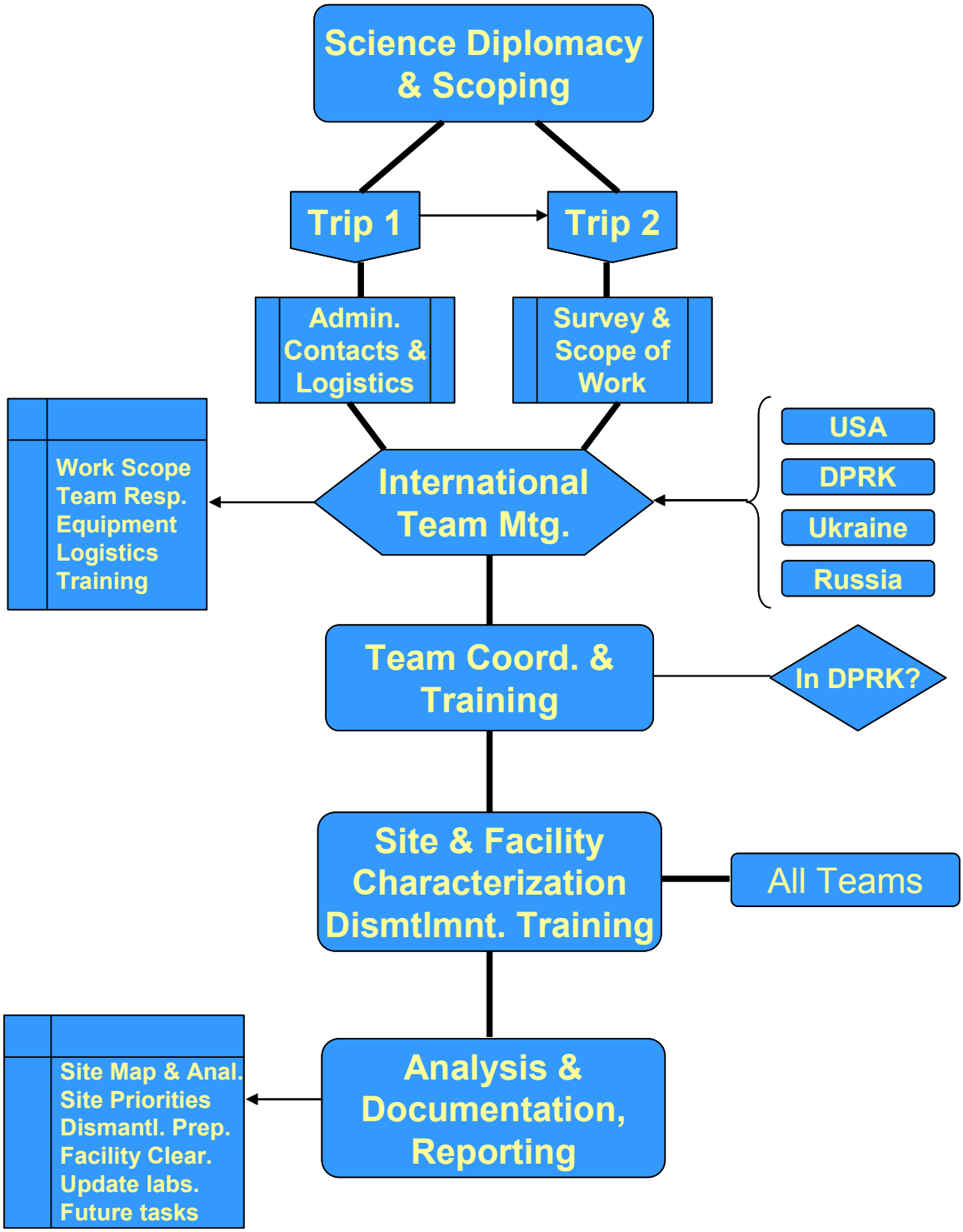
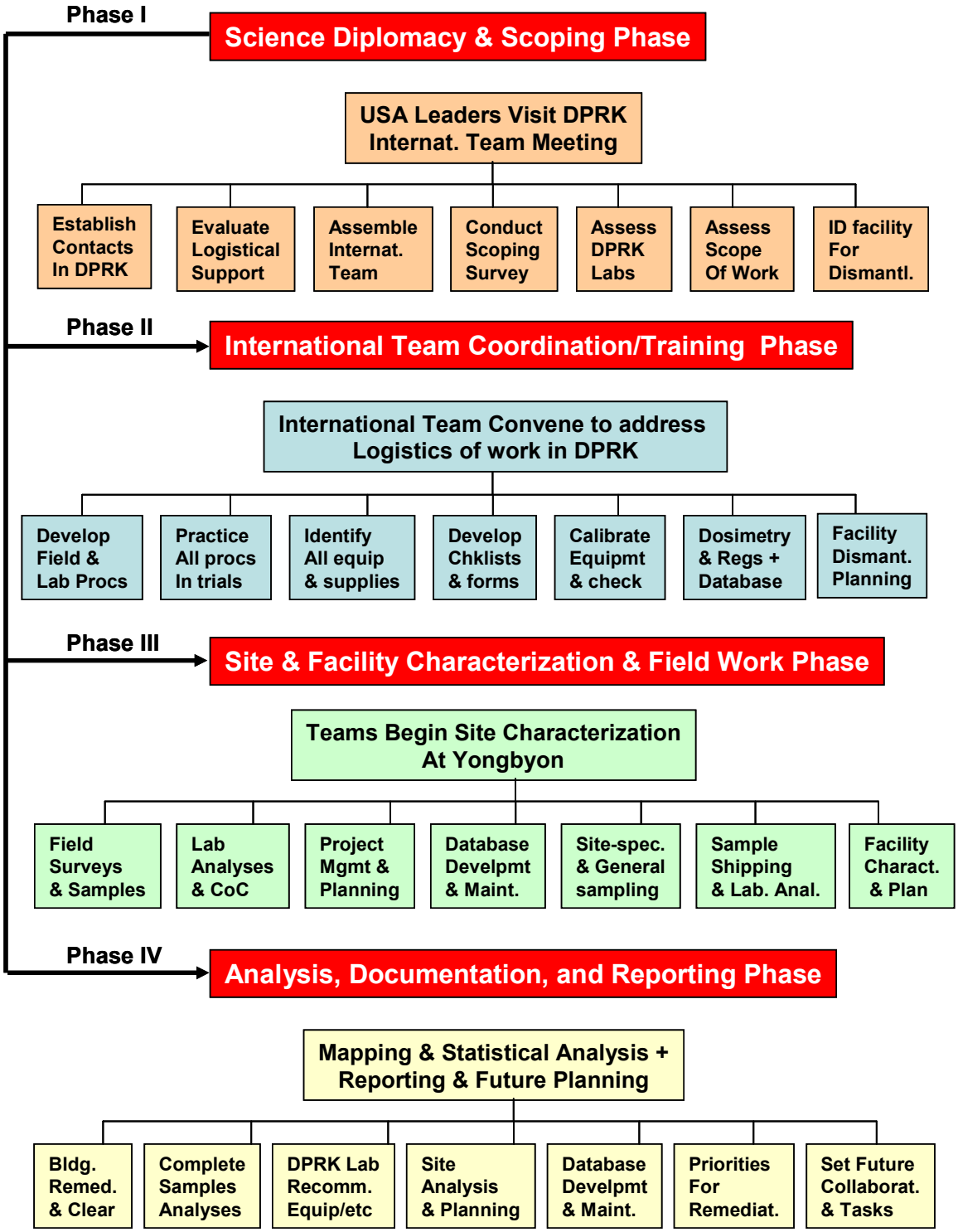


Figure 2. Schematic of the Work Plan for Site and Facility Characterization Phases at the Yongbyon Nuclear Facility.



Subsequent to the international team meeting, a workshop will be held to formulate checklists of necessary equipment and personnel protective equipment (PPE), finalize forms for field data records, laboratory and database procedures, sampling plans/maps, and dosimetry records for all personnel. Representatives from DPRK and each cooperating laboratory, as well as field survey/sampling teams, database personnel, and regulators will attend. The workshop will be hosted by the International Radioecology Laboratory in Slavutych, Ukraine, in one of the two cooperative labs in Russia, or in the DPRK if travel restrictions dictate. Mock field characterizations will be conducted to improve skills and verify equipment familiarity. Field data forms will be developed and refined to ensure that all teams collect samples in a similar manner. Equipment will be calibrated and cross-checked. Personnel training will also be provided to ensure knowledge of safety measures and emergency procedures. It is anticipated that this training workshop will require a period of two weeks and will generally follow the format established by the "Train and Engage" program conducted by Texas Tech University and the International Radioecology Laboratory (Ukraine) for 27 Iraqi personnel in June 2008. As such, the training will transition from a classroom setting to a realistic enactment wherein the responsibilities for conducting tasks will fall upon the trainees with oversight by the organizers. Assessment of environmental samples and ones obtained within facilities will be emphasized and statistical evaluations of standardized tests will be conducted using programs such as COMPASS (ORNL) to address adequacy of sampling to meet clearance criteria.

A separate training program in dosimetry control will be offered to DPRK educators from Yongbyon site. A "Train the Trainer" workshop will be conducted to tutor approximately 15 DPRK persons in radiation worker safety training programs and dosimetry control and record-keeping. The "Train the Trainer" program will require about 15 days with half of the time dedicated to learning the material. The second half of the program will be conducted by the trainees, honing their teaching skills while receiving advice from the trainers. This process has been successfully applied to rapidly expand the number of trainers available and provide service to a large worker base. Implementation of this program will enable training of many workers at the Yongbyon facility in radiation/worker safety and dosimetry control.

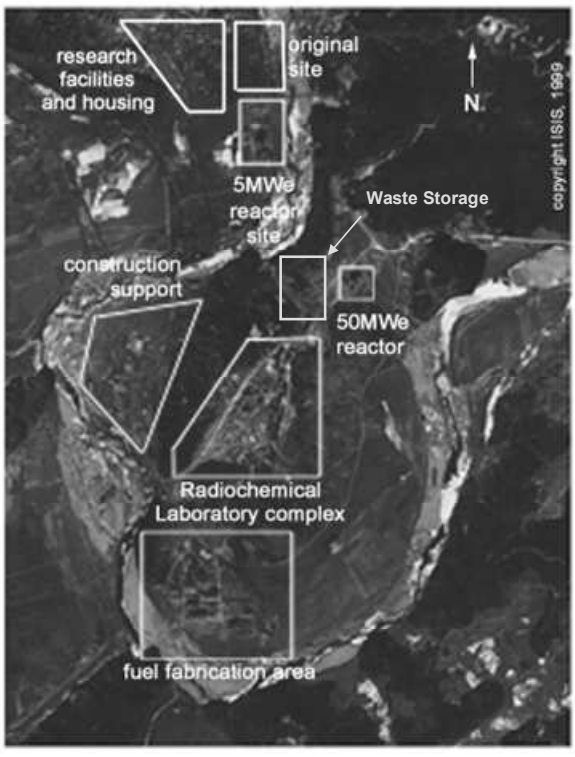


Figure 3. Satellite view of the Yongbyon Nuclear Facility showing general site activities.

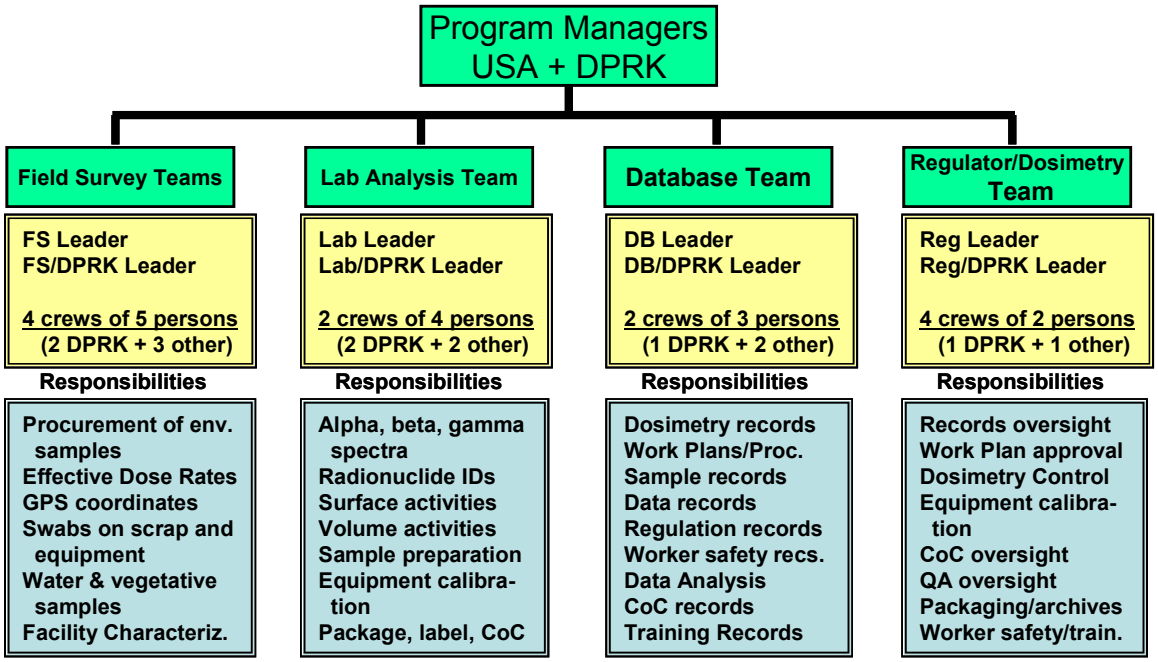


Figure 4. Composition of the teams required to conduct the site characterizations at the Yongbyon Nuclear Facility. A total of 52 persons will be assigned specific tasks; twenty-three DPRK personnel will participate. The designation "other" refers to personnel from USA, Ukraine, Russia, or other European participants.

Phase III – Site & Facility Characterization Work Phase

The field/facility sampling phase of the program will be the most demanding and labor-intensive part of site characterization. The size and complexity of the Yongbyon Nuclear Complex (Figure 3) dictate that multiple teams will be required to complete the field sampling in a reasonable period (Figure 4). Also, field sampling requires extensive and carefully managed record-keeping to ensure that quality assurance is maintained and databases are accurate. Two program managers (1 DPRK, 1 USA) will organize and oversee all activities associated with the site characterization. The program managers will work closely with team leaders from the other work teams to develop consistent procedures for performing tasks and taking readings. Together with the regulators, work plans will be written for each team prior to initiating work. Team leaders will then meet with their respective teams to review daily work plans, equipment and PPE requirements, and safety hazards that may be encountered. Emergency procedures are to be reviewed daily.

It is anticipated that four field survey teams comprised of five individuals each (2 DPRK, 3 other) will be required. Each field survey team will review work plans with two regulators (1 DPRK, 1 other) prior to beginning work. Regulators will approve for work to begin after all safety concerns have been addressed to his satisfaction. Data collected during field sampling will be transferred to database personnel (two crews of three persons; 1 DPRK, 2 other) via survey interface software developed at Texas Tech University (described below). Physical samples of soil cores, water, vegetation, swabs from scrap/equipment, and various materials will be transferred to one of the two laboratory teams (4 persons each; 2 DPRK, 2 other) via a chain of custody (CoC) form.

Laboratory teams will perform in-depth gamma, beta, and alpha spectra analyses as appropriate to the type of sample and the techniques requested in the work plan. Laboratory personnel will complete data entry for the sample numbers on the CoC forms. All physical samples will be divided into duplicate containers. Results of analyses performed at DPRK laboratories on-site at Yongbyon will be compared to those obtained on the same samples at the cooperating USA/Russian/Ukrainian/European labs. Such comparisons permit a cross-check of potential problems in techniques or equipment calibrations and detector readings at the DPRK laboratories.

Field survey teams will be assigned work plans daily for the different regions of the Yongbyon Nuclear Facility. Plans will be reviewed with the regulator prior to packing gear, donning PPEs, and traveling to their site of work. GPS coordinates will be noted at each sample site and preprinted bar-coded labels will be attached to sample containers and field forms. Effective dose rates at 1m and 15cm above the surface will be noted. In areas where there is no prior knowledge of contamination events, effective dose rates will be taken approximately 20m apart, whereas physical samples (cores) will be taken at 60m intervals. In some instances the field survey teams will encounter discarded scrap or equipment. Swabs ($100cm^2$ area) and/or physical samples will be taken in these areas as appropriate. Physical samples such as metal shards and chips of concrete may be obtained from objects showing interesting radiation readings on survey meters. Prescribed regions will therefore receive systematic geo-referenced sampling for effective dose rates and soil cores, and incidental sampling for scrap, rubble, and equipment in the region. Samples will be stored in a closed container and transported to a collection area for chain of custody transfer to the laboratory analysis team. Thermoluminescent dosimeters (TLDs) will be placed at several positions within each sampling area and left for several days. Subsequent development of the TLDs will provide accurate assessments of surface and penetrating dose rates across the Yongbyon nuclear facility. Daily activities will end with decontamination of personnel and field equipment, disposal of PPEs, and a joint meeting to discuss accomplishments and planning for the next day's activities.

Engineering safety assessments of the selected building at the Yongbyon site will be conducted by the Project Manager, Chief Engineer, and a selected Field Survey crew. Characterization of the selected building facility will be conducted on a room-to-room basis using work plans prescribed by the Project Planners and the Site Regulator. Team meetings and overviews of plans will be conducted in a manner similar to the field exercises, but will include precautions specified in the engineering safety assessments of the building. Physical samples will be transferred to the laboratory team for analysis and data maintenance will be the responsibility of the database team. All activities conducted in the facility will be overseen by the Regulators. Subsequent to the first set of analyses, remediation actions (and their consequence) will follow until each room has attained a prescribed clearance criterion level.

Phase IV – Analysis, Documentation, and Reporting Phase

The objectives of the final phase of the site characterization are to conduct complete analyses of all physical samples, make recommendations for equipment purchases and procedures to bring the DPRK laboratories into compliance with IAEA-compliant labs, write a collaborative report

detailing environmental contamination and hazards at the Yongbyon Nuclear Facility, and discuss the subsequent stage in characterizations needed to dismantle and/or disable specific nuclear facilities. Soils, physical samples, swabs, will be analyzed at the cooperating laboratories in collaboration with participating DPRK laboratory personnel. Standard radiochemical and spectroscopic analyses as well as inductively coupled mass-spec and other spectrometric methods will be employed. Because all cooperating labs will likely have different analytical capabilities, DPRK personnel and samples will be divided to ensure a broad collective expertise. Recommendations for several critical decisions can be made at this time, including:

- Zones that may qualify as unrestricted use, limited activity, or restricted activity.
- Zones and travel paths that will serve as waste storage areas.
- Signage and fenced areas to restrict activities.
- Priority criteria for site clean-up/remediation to meet future use objectives.
- Laboratory and engineering needs to meet remediation and dismantlement needs.
- Regulations and guidelines needed for decision-making.
- Formulation of plans to dismantle the selected building and sort the result waste stream.
- Personnel needs to initiate remediation and dismantlement needs.
- Expanded collaboration and training needs.

The next stage of work should move to assessment of the engineering requirements for dismantlement of buildings and the complex requirements for facility characterizations in accordance with international standards. Emphasis should be placed on using the "Multi-agency Radiation Survey and Site Investigation Manual" (MARSSIM, USEPA). Although this document may be overly complex for most applications in the DPRK, it can serve as a foundation for introducing international standards and demonstrate the need for growth in the regulatory environment and inter-ministerial communication in the DPRK.

Anticipated Personnel Needs

A breakdown of DPRK and other personnel required for the site characterization (1) program and future related programs for (2) Characterization of facilities targeted for dismantling, (3) initiating dismantlement of a preliminary facility, and (4) commencing dismantlement of multiple facilities, is provided in Figures 5 and 6 below.

Figure 5. Anticipated personnel needs for DPRK and other countries to conduct site characterization and related future activities at Yongbyon Nuclear Facility.

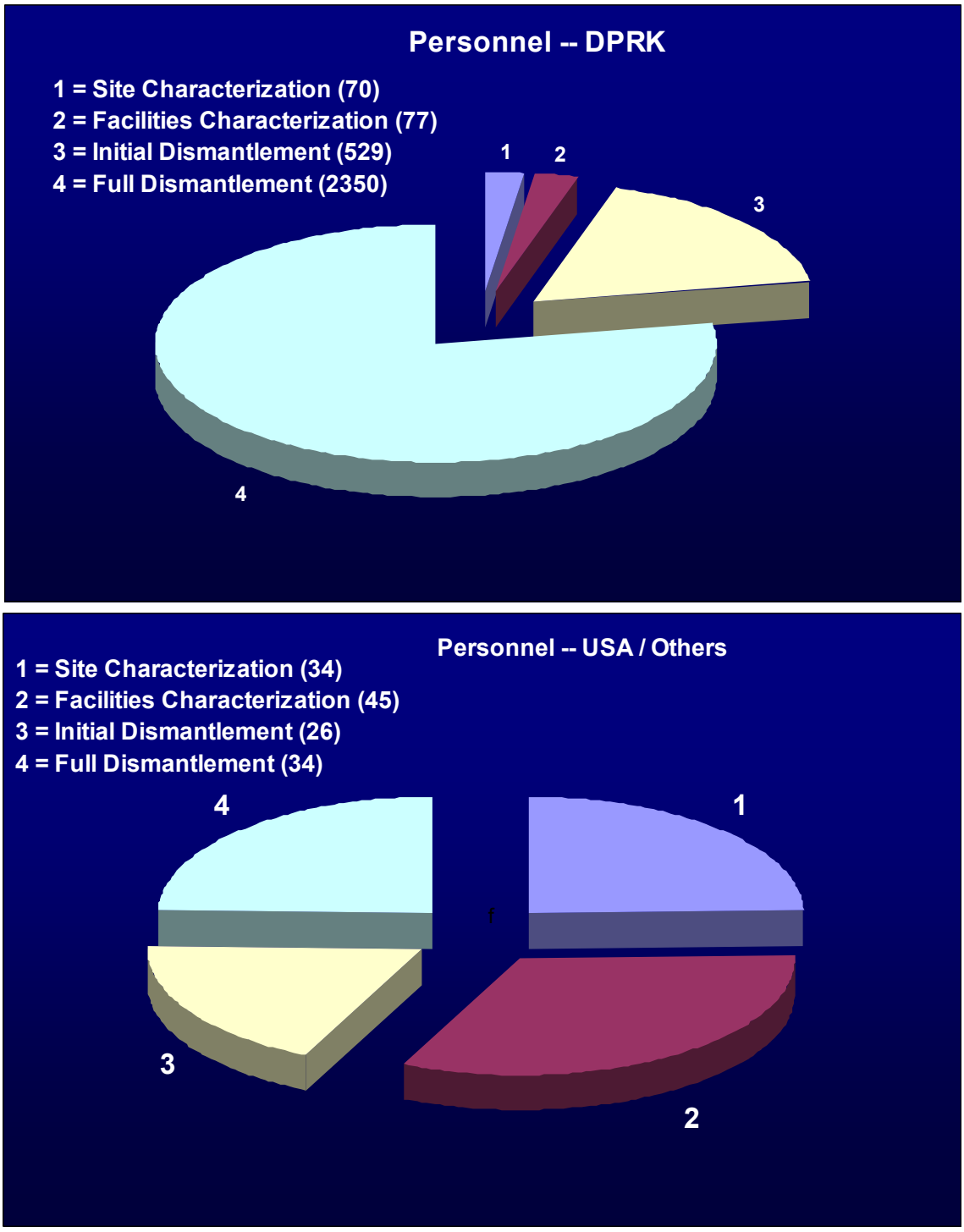
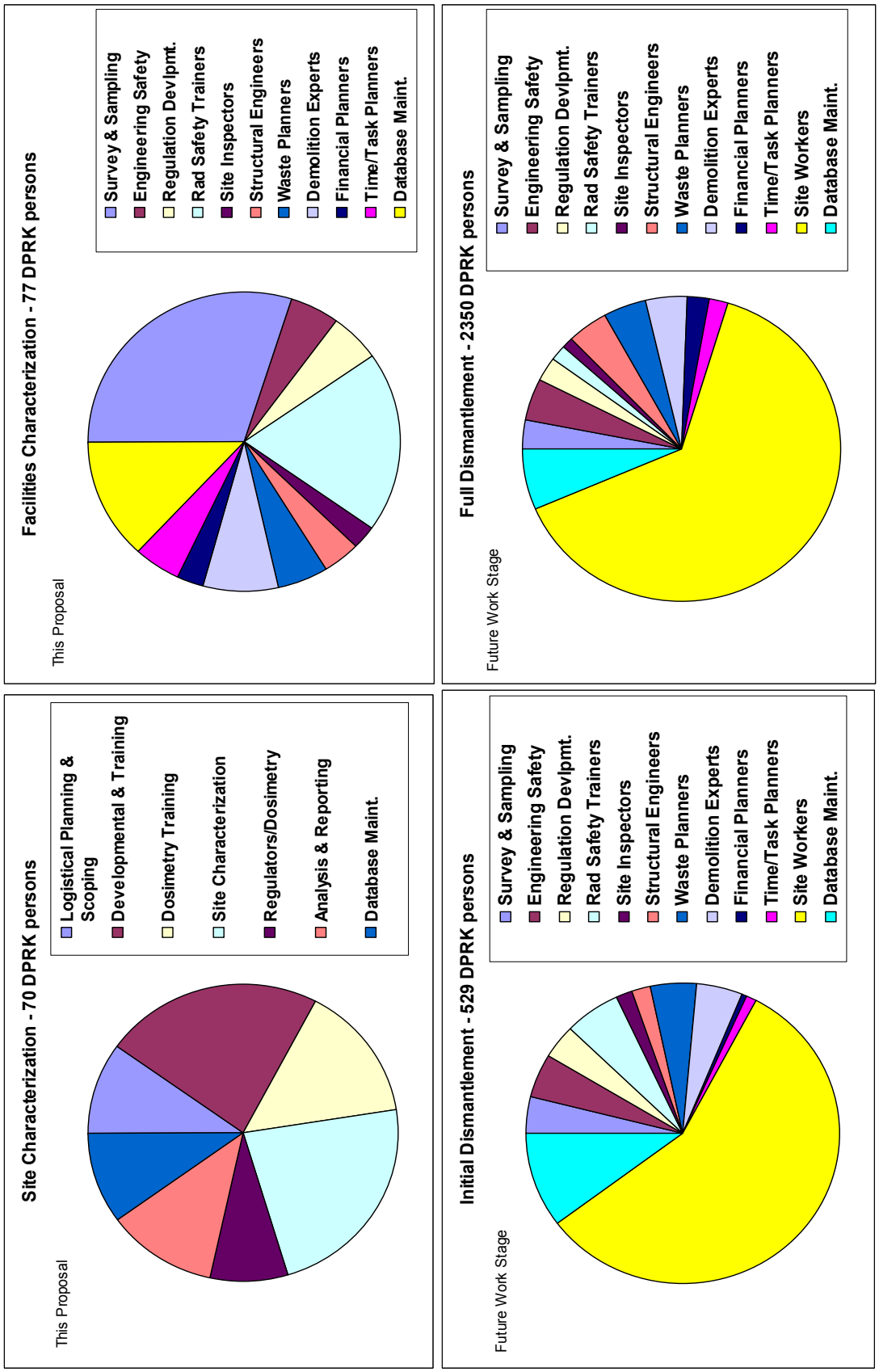


Figure 6. Anticipated DPRK work force required for site and facility characterization (note that many workers overlap between these two programs) and future related activities at Yongbyon.



Yongbyon Nuclear Facility Site & Facility Characterization

Budget Summary

Total First year:	**$2,447,240.**
Total Second year:	**$3,452,760.**
Total Budget Amount:	**$5,900,000.**

Budgeted amounts include funds for Salaries, Travel (foreign and domestic), Equipment and supplies, Expendable supplies, Participating Lab Costs, Redirection Costs, Shipping Costs, and Overhead/Administrative Costs (@26%).