Best Practices In The Development Of Scientific Drilling Projects

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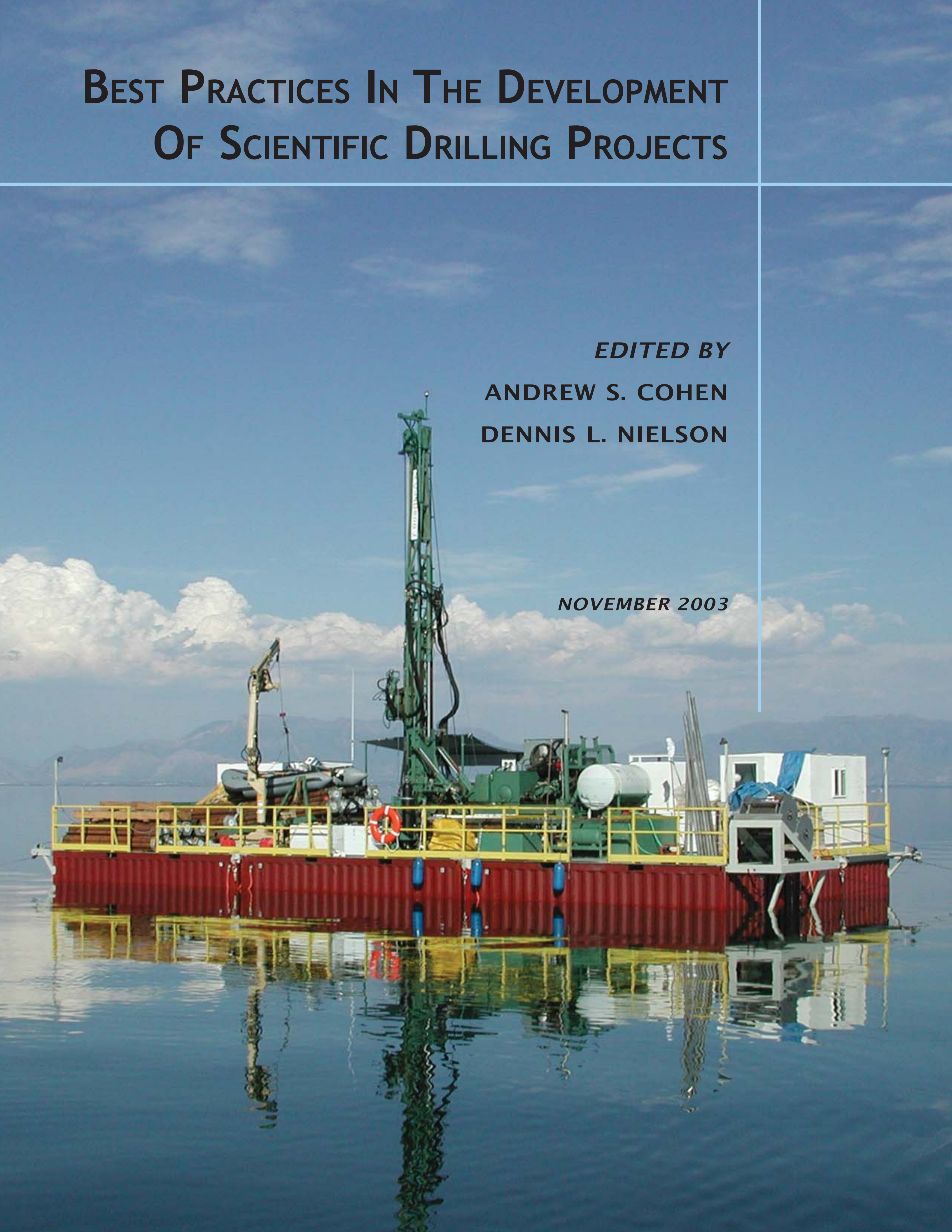

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Executive Summary

Continental Scientific Drilling has an established record in the advancement of the earth sciences. The Continental Scientific Drilling Program was carried out in the U. S. between 1985 and 1994 and has been succeeded by the International Continental Scientific Drilling Program. Currently, projects of national and international interest are underway, and the distinction between continental and ocean drilling is being crossed. However, the process of developing a scientific drilling project, particularly one of international scope, is complex and both scientists and funding agencies need to understand the practical requirements that lead to a successful project.

In an effort to provide input to funding agencies concerning the scientist's perspective of the proposal process and to provide a road map for scientists contemplating a scientific drilling proposal, DOSECC convened a workshop in May 2003 to address Best Practices in the Development of Scientific Drilling Projects. This report defines the stages from initial concept through the post-drilling activities, and presents recommendations that will be of interest for proponents of scientific drilling projects, particularly those that will have international participation.

The initial stage of a drilling project is presented in the context of Concept Development and Project Team Formation. A scientific drilling project is a complex undertaking, and the make up of the team of scientific investigators and drilling experts is critical for success. The best approach to initiate a project is a workshop where the project team is formed and plans are established for preparing a scientific drilling proposal. At this early stage, funding options are discussed and the fund-raising responsibilities of investigators are established. Interpersonal relationships are extremely important, and a cooperative atmosphere must be established at this early stage. Following the workshop, the PI's must decide whether to move the project to the proposal stage.

The next component of the project development process is described as the Critical Background for the Preparation of a Successful Proposal. This stage is where all of the information for the preparation of a successful proposal comes together. The workshop may identify additional scientific investigations necessary to complete the proposal. A detailed drilling plan and an administrative plan will be required for the proposal as will a schedule that takes into account the integration of the scientific and drilling requirements of the project. It is also necessary for the project team to establish policies with respect to sample access and publications. Since there will commonly be applications to multiple funding agencies, the mechanics of proposal preparation and the requirements and timing of different funding agencies will influence the proposal preparation process.

Funding for scientific drilling projects commonly involves multiple agencies of different nationalities that may also require their funding to be used for specific purposes. Also, it has become common for some funding agencies to separate funding for drilling from the subsequent scientific investigations. Some investigators may not be able to satisfy their funding obligations and may have to leave the project, making a reevaluation of project scope and staffing necessary.

Following funding, the scientific and engineering team enters a predrilling phase of project preparation that this report terms Project Coordination. This stage requires regular communication between the principal project participants. This is the period during which contracts are established, and budgets are updated and finalized. Shortly before operations are initiated, the PIs need to hold a kickoff meeting and assure their procedures are in place for communication with the project team, sponsors and the scientific drilling community.

Logistics and Project Execution describes many of the logistical details that must be addressed before drilling equipment and science and drilling crews arrive at the location. At this time, final decisions will be made concerning the people who will be responsible for different aspects of the project. For instance, it may be beneficial to designate a person who will be responsible for handing onsite logistics. Permitting requirements vary widely and must be completed at this stage of the process. Mobilization and demobilization must be addressed, and arrangements for site security should be completed. An environmental and pollution prevention review should also take place. Since scientific drilling projects will be of interest to the local population, a program of public outreach should be planned.

Onsite Management of Drilling Operations describes activities and decisions to be expected while the drilling operations are in progress. Personnel and environmental safety are important components during operations. Unforeseen circumstances may require deviations from the drilling plan, and a formal management structure is required to avoid confusion. Timely dissemination of information to project team members and sponsoring organizations is essential. Also, a scientific drilling operation provides the opportunity to hold workshops that should be attended by proponents of future projects.

Following the completion of operations, the Post-Drilling considerations will involve sample handling and initiation of scientific investigations. It is important to publicize the initial results to other scientists, educational organizations and the public at large as soon as possible following drilling.

Introduction

Within the US science establishment, scientific drilling on the continents has followed a separate path from the Ocean Drilling Program (ODP). Between 1985 and 1994, a U.S. Continental Scientific Drilling Program (CSDP) was established under the guidance of an Interagency Coordinating Group (ICG) formed by the National Science Foundation (NSF), U. S. Geological Survey (USGS) and the Department of Energy (DOE). The scientific basis for this program was described in Zoback et al. (1988), and that report concluded "...it is fair to say that there is no branch of the solid earth sciences that would not benefit greatly from a continental scientific drilling program." In order to aid the ICG in the implementation of scientific drilling projects, DOSECC (Drilling, Observation and Sampling of the Earth's Continental Crust, Inc.) was formed in 1984. The CSDP completed a series of successful projects that involved a total of 948 individuals representing 184 institutions.

In 1994, the International Continental Scientific Drilling Program (ICDP) was established through funding from the US, Germany and Japan (Zoback and Emmermann, 1993). This program resides at the GeoForschungs Zentrum in Potsdam, Germany and, since its establishment, it has expanded to include many other member countries. ICDP funding is generally restricted to drilling operations, and it typically funds only a fraction of total drilling costs. Project proponents must raise the additional funds necessary for drilling and all funds required for scientific investigations from the scientific funding agencies of their respective countries. As a consequence of the international aspect of ICDP, legitimate scientific drilling projects may not qualify for funding because the scope of the proposed investigation is of regional or national rather than international interest.

In keeping with ICDP's theme, a recent trend within the scientific drilling community is for projects to involve principal investigators from different countries who have multidisciplinary and interdisciplinary scientific objectives. These projects utilize multiple international funding sources that tend to be earmarked for specific components of the project. International cooperation and the involvement of multiple funding agencies increase the complexity of organizing, funding and implementing drilling projects.

This increased complexity requires a cooperative team approach by the project participants that must include scientific investigators as well as drilling experts. A high degree of communication is necessary for the establishment of schedules, budgets, logistics and operations as well as personnel and environmental safety plans. Communication should involve face-to-face meetings by the project participants, that are both more difficult and more necessary in the case of international projects. Project success requires that all principals satisfy their obligations to the project team.

Investigators wishing to initiate a scientific drilling project are faced with a number of hurdles. First, they must understand the procedures necessary to navigate through an array of requirements from different funding agencies. Second, they must understand the components of a successful scientific drilling project. Third, they must circumnavigate a number of gaps in the process that could affect both the successful outcome as well as their ability to participate in the associated scientific investigations. This report is intended to address these issues by providing a road map for investigators that discusses the numerous stages through which a continental drilling project must evolve in the current operational and funding environment.

In May 2003, a panel of experts convened in Minneapolis to review the current process for developing a scientific drilling project, this document presents the results of those discussions. Recommendations for improving the supporting infrastructure for U.S. scientists have been proposed separately.

The following sections address the components of best practices for initiating and completing a scientific drilling project. Figure 1 is a flow chart showing the steps that were identified by the workshop participants. The following topics were addressed by breakout groups and form the basis for this report.

- Concept and Project Team Formation
- Background for Preparation of a Proposal
- Funding
- Project Coordination
- Logistics and Project Execution
- Management of Drilling Operations

Throughout the presentation that follows, the major elements in the development and operation of a successful continental drilling project and the roles of key participants are discussed. Although the titles and job descriptions may vary, the roles described are required to plan and implement a project successfully. Appendix 1 lists the roles and responsibilities of key individuals and serves as a reference for the following discussion.

The panel also recognized that scientific drilling projects display a range of complexity from a single investigator who hires a local drilling contractor through an international multi-investigator deep drilling project with a budget of more than $10 million. The following discussion is weighted toward the larger, more complex projects to provide a more extensive discussion of options.

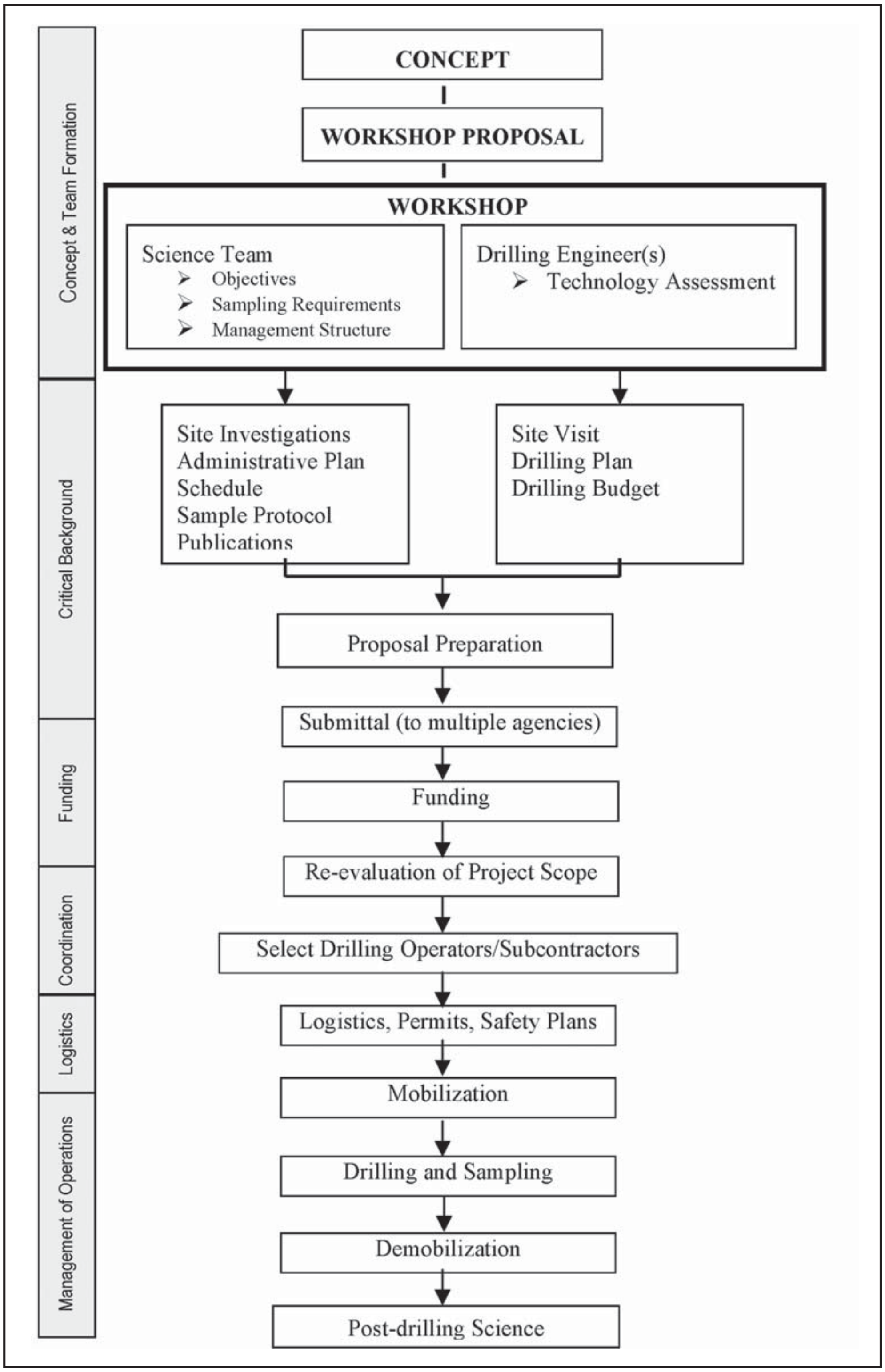

Figure 1. Scientific Drilling Flow Chart.

Concept Development and Project Team Formation

Project Initiation

A scientific drilling project is generally initiated by a small group of scientists who require drilling as a research tool. Scientists who are contemplating a continental scientific drilling project need to recognize from the outset that they are embarking on a large, complex and expensive endeavor; one that currently has few clear road maps. Thus it is incumbent upon project proponents that they approach the problem realistically, while at the same time framing their project in a way that is likely to excite the wider scientific community.

A scientific drilling project must be based on a very strong scientific premise to be a successful candidate for funding. Projects that cannot formulate clear and broadly appreciated scientific goals are unlikely to garner the support needed to proceed. Thus, from the outset PIs need to "think big" and state in a few words the "global" significance of their project. In addition, they need to be able to articulate the reason that drilling is the key to attaining their scientific objectives. These statements can be integrative but should not exceed two or three key points so as not to dilute the core message. Potential PIs without prior experience in drilling project development should seek out advice at a very early stage from experienced colleagues who may have a better grasp of the importance of this goal setting process.

Identifying A Team

Most successful drilling projects result from the efforts of a small group of extremely committed scientists who are willing to take the lead and invest large amounts of enthusiasm, time and energy. Conversely many projects fail because the participants do not have a sufficiently high level of commitment, or because the commitment and effort falls disproportionately on a single individual who lacks the ability to organize the project alone.

We refer to the core group of committed scientists as the Principal Investigators (PIs). A successful PI team will consist of individuals with very different skills, some who understand broad scientific issues (the "big-thinkers") who can give direction to formulating the project's overall message and objectives, some with technical expertise or interpersonal skills, that are important for keeping the project on track, and some with political savvy, who can negotiate the complex set of activities needed to fund and operate the project. It is important to identify a core team of PIs who agree on a minimal set of objectives required for the success of the project. All of these aspects will become important at different stages of the progress of the proposal and progression of operations. PIs need to give this issue some attention as they develop their core team and add additional participants.

In the earliest phases of project development, formulation of scientific objectives and definition of study locations, depths and numbers of holes, are likely to dominate PIs' discussions. Initially these are best addressed in small informal groups, through e-mail or phone conversations. As the concept begins to mature, however, it will quickly become important for the proponents to enter into a more formal and larger-scale team building phase. PIs need to do this with their eyes open to a host of possible problems. Probably the most common mistake is recruitment of co-investigators who are not really committed to the project. These may be identified out of convenience ("scientist X is in my department and might be willing to be involved") or from misinterpretation of casual but noncommittal conversations. Such individuals may not have the commitment to "stay the course" through what is likely to be a long and arduous road to an actual drilling campaign. Projects with Co-PIs who do not have a strong interest, or who are participating as a result of top-down directives are less likely to be successful. Clearly it is sometimes necessary to recruit individuals with specific technical expertise, but the core PIs should be alert to the possibility that such individuals may be over committed. It is essential to recruit individuals with a direct professional interest in the project's scientific objectives to maximize the likelihood that their interest will be strong. Friction can arise if factions within a drilling research team feel that other workers were foisted on them. Interpersonal problems that develop early in the project are unlikely to go away later.

Formation of a team of highly interested participants is best accomplished through an openly advertised workshop where participation is self-selected. Very early in the drilling planning process science teams should seek funding to hold such meetings.

Organizing A Drilling Workshop

A drilling workshop is generally the first full public airing of the scientific drilling concept. The project should not be presented as an accomplished fact, but neither should it be so immature that time is wasted in overly wide-ranging discussions. This issue is usually addressed during review of the workshop proposal. The workshop gives interested scientists a chance to become involved and shape the program, while at the same time giving the leaders helpful feedback, a general sense of the level of enthusiasm and "marketability", and input on key contributors and proponents. Goals of the workshop should be to:

- Establish a core PI team (project leaders, ~3)
- Establish science teams, chaired by PIs
- Refine and prioritize scientific objectives
- Formulate a drilling strategy
- Review the feasibility and cost ranges of different alternatives
- Develop an overall project plan.

To insure a broad range of scientific participation, the workshop should be advertised in a widely read scientific newsletter. The response to this can aid the PIs by strengthening the scientific team and attracting complementary science.

The purpose of a workshop is to organize and plan. PIs should take considerable pains to insure that participants understand these objectives through pre-meeting circulars, websites, and e-mail correspondence.

Although discussion of prior results is valuable in allowing individual participants to demonstrate their interest in the project, the PIs should make sure that this component does not dominate the time available for the meeting. Allotting time for plenary discussion of major science objectives and technical issues is critical.

In reviewing the workshop participant list, the PIs need to ask themselves if the capabilities of candidate team members are adequate for the mission. Well before the workshop, the core team should go through the exercise of identifying the necessary and appropriate scientific and technical/ engineering expertise required for their objectives to be met and making sure each of those areas is well represented in the participant list.

PIs need to insure group cooperation and communication. At a drilling workshop many ideas will be presented, often covering conceptual ground well beyond what the core science team originally anticipated. The PI team needs to think carefully about the pluses and minuses of altering its direction to accommodate additional team members with different objectives. The PIs also need to pay close attention not only to what is being said and by whom, but also to how group interactions develop. A successful team will be one where the participants are determined by a consensus of other scientists. Core PIs should avoid artificial groupings of researchers with highly polarized approaches to science. In international projects, PIs need to be aware of differences in approach to science that are culturally based and should adjust their working relationship with their colleagues accordingly if they are to avoid problems later.

A major outcome of the workshop should be a prioritization of the scientific objectives of the drilling program that identifies the following.

1. The core scientific sampling and on-site measurement program that is required for the success of the project (i.e., the on-site work that would be sufficient to declare the project had achieved the major goals of drilling).
2. The highest priority science that must be completed in order to declare the project a success.
3. Worthwhile additional scientific studies that should be carried out as time and resources permit.
4. Lower priority add-on science.

Before convening a drilling workshop, the core PI team should begin discussions with drilling experts from organizations such as DOSECC, the commercial drilling industry, ICDP and engineering groups familiar with the challenges likely to be faced by the project. Core PIs are strongly encouraged to make use of the DOSECC (*www.dosecc.org*) and ICDP (*www.icdp-online.org*) websites to obtain information on the drilling and logging equipment available to the scientific community. It is critical to begin these discussions before a drilling workshop because some suggested directions of inquiry may be impractical for technical reasons. Before, during and after the workshop there is a need to continuously integrate the scientific, logistical and technological needs of the project. Appendix 2 is a planning checklist of topics that should be considered in project formulation.

PIs should identify necessary drilling expertise needed to guide them through the development of their technical proposal. Small projects using standard drilling techniques may not require a dedicated engineer to guide the project leaders though the project design. However, PIs developing large projects, or ones using innovative technology, should consider hiring a competent and independent engineer to help them prepare the drilling plan and budget. This person will also function as the team's representative, assist in selection of a drilling contractor and serve as the interface with their drilling operator. PIs may need to budget ~$500/day for the services of such a person.

During the drilling workshop, the PIs need to insure that consideration is given to all critical points necessary to allow the project to move forward to a proposal development phase. Important issues include the following:

1. Have important scientific questions and information gaps been identified?
2. Have the PIs and engineers made an adequate assessment of the technology required for the project?
3. Is there general agreement about a proposal strategy and/or potential funding sources?
4. Are there a sufficient number of committed participants for the project to succeed?
5. Is there good agreement between scientific and technical participants concerning objectives and general plans?
6. Are additional site surveys or feasibility studies necessary?

PIs will spend a considerable amount of their own and other people's time organizing and participating in the meeting. It is imperative that the discussion doesn't get bogged down on side issues or turn into a mini-symposium of individual investigators' research without adequate time being allotted to discussion of the road ahead.

Planning for sampling and logging (both core and geophysical) should begin during the workshop. Frequently, the enthusiasm of co-investigators will depend on their perception of how valuable the cores and holes will be to their objectives. A thoroughly discussed and well conceived logging plan will go a long way towards satisfying these concerns for many participants. On-site core logging is strongly advised and PIs may wish to discuss this option during the workshop. ICDP currently has a GeoTek logging system available for use on ICDP projects and other GeoTek systems are probably available within the scientific drilling community. At present, downhole logging can be arranged through ICDP using slim-hole logging tools. PIs should consider the possibilities of logging while drilling (LWD) technology, as it becomes more readily available.

Depending on the complexity of the drilling project, more than one workshop may be required to organize and provide input to the proposal. This may be the case if the initial workshop finds the concept to be too immature to justify a proposal. It also may be the case if the PIs determine it is necessary to address technology (drilling) issues separately from scientific issues, particularly if the proposed drilling presents unusual or difficult technological challenges.

Moving Ahead

Shortly after a drilling workshop is held, the PI team needs to decide if there are sufficient information, scientific questions and expertise to move ahead to a proposal planning stage. PIs need to assess this question honestly and carefully; the time invested in organizing a workshop is trivial compared with what comes next. PIs need to determine if they have the expertise to make qualified decisions. They should know the limits of their knowledge and not be afraid to seek out additional help on key decisions. Some scientific drilling projects have benefited greatly from input from technical and scientific advisory groups.

PIs should understand the ramifications of using particular sources of funding. Different agencies have different rules concerning the complex procedures involved in proposing a project. PIs need to educate themselves about such differences if they are considering multiple funding sources.

By this stage, if not earlier, the core science group should identify its project leaders, those who will be responsible for making decisions. The team building process also involves pruning the list of goals of the project to an achievable whole. There is a fine balance between learning about new and exciting directions from workshop participants and becoming distracted by directions that are unlikely to hold the attention of the team or the scientific community during the proposal review process. It is also valuable for the PIs to define the decision making process among project leaders as well as between project leaders and collaborators at this time. The management structure may evolve over the course of the project, but unfortunate interpersonal consequences can result if the project proceeds to the proposal submission stage without leadership and collaborator selection/coordination issues having been adequately addressed.

Part of establishing a scientific management structure in the project development stage involves ensuring that both the immediate scientific community and the key program officers at relevant funding agencies understand this structure. It is useful to lay out an explicit organizational structure with identified responsibilities prior to proposal submission.

By the end of the workshop, many aspects of the drilling project will have been decided. However, it is likely that additional information will be required prior to submittal of a proposal.

Critical Background for Preparation of a Successful Proposal

Determination of technological requirements and expertise

Once a scientific and engineering workshop has been held, the PIs are in a position to begin preparing their drilling proposal. PIs by this time will have paid close attention to scientific objectives and hypotheses to be tested through drilling, but they may have given incomplete consideration to the technical aspects that can also make or break a proposal. PIs should pay particular attention to the recommendations of their drilling workshop in areas such as technology and safety and environmental concerns where their expertise may be more limited.

Post-workshop, On-Site Investigations

Many scientific and technical questions may arise from a drilling workshop that can only be addressed by additional surveys. Despite the perception PIs may have that more work is unnecessary or redundant, the investigators must pay close attention to such recommendations, especially when they arise from experts in the field. The same questions are likely to be raised by panelists at the time the proposal is reviewed.

Although the PIs may have a great deal of experience working in the area where drilling is proposed, it is unlikely that they will have considered all of the challenges from the drilling engineering standpoint. Therefore, prospective PIs are well advised to organize a site visit with their drilling engineer in the early stages of post-workshop planning. The engineer will have questions on a wide range of subjects, from road/port conditions to accommodations and meals for the crew, to safety hazards. Almost all of these are best considered when the engineer is on-site and can more easily anticipate potential problems.

Establishing a drilling plan

A major evaluation point of any scientific drilling project will be the quality of its drilling plan. In the pre-funding period the plan will be a more generalized document, which will evolve as the resources available and timetable become clearer. Thus we will return to the development of a drilling plan at several points in this document. The details of the drilling plan and schedule must be discussed between the PIs and their engineer prior to final proposal submission to insure that the proposed budget is adequate for the operations anticipated. The initial schedule should be science driven (i.e., when will everything be in place to do the best science). However, a host of secondary considerations need to be taken under advisement in developing the plan. At some sites weather windows are a strong factor in scheduling, for example, in determining drill rig transport to off-road locations, or because of wave problems in lake or coastal sites. The best available synoptic climate information should be used to make scheduling decisions. Once funding is in place and contracts are let, it will be more difficult and expensive to effect a change in the schedule.

The planning document should include a written agreement among project participants outlining their respective responsibilities to the project. Although such a document is not currently required by funding agencies it should be a standard element of good planning to insure proper operation of drilling activities.

Establishing an Administrative Plan

The administration of a scientific drilling project can be complex and should be discussed between the PIs and drilling engineer or knowledgeable consultants. This role involves establishing subcontracts, tracking expenses, verifying invoices and paying vendors. Large drilling projects will often have 10 to 20 subcontractors. Unexpected events are common in drilling projects, and the administrator must be prepared to establish new subcontracts and modify expected spending patterns quickly. Expenses must be tracked carefully and financial status reports must be available on a daily basis if needed. For these reasons, administration of a drilling project, particularly one that is large, is often run through a general contractor. The use of a general contractor will have a cost implication; and therefore, this aspect of the project must be determined before budgets are submitted.

Scheduling project phases

Given the complexity inherent in scientific drilling projects, PIs need to pay close attention to project scheduling. Early in the proposal development phase, the PIs should determine a realistic timeline of specific activities. This includes development of specialized equipment/tools, predrilling preparation activities, equipment shipping and project mobilization, drilling, sampling and logging, demobilization, post-drilling sample shipment and handling, and post-drilling science. Frequently this schedule will be driven by external realities imposed by weather windows, funding cycles, schedule conflicts, and equipment availability, all factors which may not be easy to synchronize.

Sample and data access/ distribution procedures

Core handling, including archiving and storage, is an issue that merits particular attention because much of the value of drilling resides with the long-term archiving and preservation of the samples collected. For the US lake-drilling community, the post-drilling handling and storage of cores is currently managed by LacCore, the National Lake Core Repository located at the University of Minnesota. PIs in lake drilling projects should consult with LacCore to formulate a sample preservation/state/ archival plan.

PIs should be aware that funding agencies differ in their requirements for sample access. PIs must familiarize themselves with these rules from a very early point in detailed planning, particularly when multiple funding sources are envisioned. The DOSECC website (http://www.dosecc.org/html/ documents.html) links to a table that summarizes sample access policies of different organizations.

As part of the project plan, the core PIs should lay out a process for distributing samples, deciding sampling priorities, and generally insuring that samples will be used most efficiently. For example, careful forethought on the part of the PIs will establish that materials subject to nondestructive analyses can be subsequently used in destructive analyses. PIs are strongly urged to establish a sampling flow chart that plots the fate of materials obtained from working core splits, to insure maximal benefit to the scientific community and to reduce confusion and friction between different groups of researchers studying the same core.

Communication of results and decisions regarding publications

PIs are urged to follow the successful ODP model of publication planning. In brief, the PIs and their collaborators should have a plan for submission of publications (including authorship) following conclusion of drilling. PIs should make every effort to rapidly publish their initial results in summary form in journals such as EOS, Geotimes, etc. Generally it should be understood among the science team that such publication should be coauthored by the scientific party of the project, including PIs and other co-investigators heavily involved in various drilling and early post-drilling aspects.

Preparation Of A Successful Proposal

PIs should work closely with their engineer in developing drilling budgets. There may be several options for tackling a particular drilling project with pluses and minuses attached to each. PIs should go through a careful cost-benefit analysis with their engineer. PIs should be particularly careful not to become wedded to a specific technology without considering alternatives. Cost estimation should be done with a contingency of ~20% to accommodate unforeseen difficulties and a probable time lag of approximately two years from proposal submission to drilling time. It is important to remember that budgets will be fixed when a grant is awarded. However, drilling costs are not fixed and always seem to increase with time. Experience shows that projects that are delayed suffer financial problems as a consequence.

An initial drilling proposal should be the product of the workshop; however, it is likely to go through a number of iterations during the peer and panel review process. Potential PIs should be aware that different funding agencies organize this review process in very different ways. Also, funding agencies currently have different policies with respect to mentoring reviews prior to final project evaluation. The ICDP proposal process encourages the submission of a pre-proposal to receive general review and advice from the ICDP Science Advisory Group. Similarly, NSF's Continental Dynamics Program encourages preliminary proposals. PIs are encouraged to take advantage of this free advice.

Serious problems can arise if the PIs do not understand the policies of different funding agencies. The PI team is strongly advised to seek advice on appropriate strategies from scientists who have trodden the path before them.

PIs have commonly used a strategy of writing a master proposal that outlines the entire scope of the project. This includes the entire statement of work as well as the complete budget. Individuals can use this document to support funding requests to their respective funding agencies.

Funding

The funding of continental drilling projects is typically more complex than for stand-alone research projects. Increasingly, scientific drilling projects utilize multiple funding sources that commonly include NSF, ICDP and the scientific funding agencies of the international project participants. There are a number of difficulties that PIs may experience using multi-agency funding.

- Different organizations have different schedules for proposal submittal and funding.
- Some funding is restricted, in that different agencies, or even different sections of the same agency, may require their funds be used for particular aspects of the project.
- Funding for drilling activities is separated from the funding for scientific investigations. The rationale for this is that drilling is risky and the amount of core available for analysis is not assured. However, it is necessary for the project proponents to discuss the timing of funding with agency representatives prior to proposal submittal so that science funding can be scheduled to accommodate the expected amount of sample. Separate funding of drilling and science raises the possibility that PIs could be able to do all the work in sample collection but not be able to perform their scientific studies before samples come off a moratorium period and are available to the community at large.
- There may be gaps in funding at critical points. In particular, funding for project coordination meetings between participants, and advisory panels, is often neglected.
- The timing of funding is critical to the efficient management of a scientific drilling project. Potential PIs need to be aware of the current limitations, and funding agencies need to be alerted to the timing problems that complex funding processes engender.

Multi-agency proposals have the drawback that one or more funding entities may reject the proposal. If that happens, the PIs must reevaluate the scope of the project as well as the level of participation of different investigators. It is often the case that a more limited but worthwhile range of scientific objectives can be met at lower cost than originally proposed. This also may be the point where some team members are forced to drop out due to lack of support. The agencies that have agreed to sponsor the project may be able to provide supplemental funding, although that may require another funding cycle with associated delays.

Project Coordination

Once a scientific drilling project has been funded, the science and engineering team enters the predrilling phase of project preparation. This intense, detailed planning process typically involves an array of expertise in final site selections, contracting, borehole design, science, and permitting. The PIs should monitor who will be making decisions on specific activities, how RFPs are to be developed for subcontracts, how the bidding process will proceed, and how contractors and subcontractors are to be reviewed for performance. Depending on the scope and complexity of the drilling operation, this task may be assigned to one of the PIs, the drilling engineer, or an advisory group. PIs may be in the best position to understand potential problems that will require contingency planning, for example adverse or dangerous drilling conditions, adverse weather or civil unrest. A small focused workshop involving both scientists and drilling experts may be necessary at this stage to consider site selection details, technological issues, materials and supplies and instrumentation to be used. Based on any plan revisions adopted at this point, PIs should implement supplementary safety, environmental and budget reviews. PIs should establish a schedule for regular meetings and/or conference calls if required by location. PIs should view their planning document as a general template for activities, but should update it regularly as information, costs and conditions change prior to drilling. Good communication between the science and drilling team is essential. Inevitably, compromises will be necessary between scientific goals and technical and budget realities.

Selecting a Drilling Operator

Since most scientific drilling projects conducted by US-based PIs will be sponsored by the Federal Government, the use of a commercial drilling contractor will require a procurement with a public notification, bid package, review and award. Although this is a step that could happen prior to proposal submission, in practice, it takes place after funding is in hand. The time span between proposal submission and project implementation is long enough (~2 years) that bids would not be valid for that length of time.

There are several cost options that are commonly used in the drilling industry, including turnkey, day rate and footage rate contracts. A turnkey contract requests that specified work be completed for a fixed cost. The disadvantage of such a contract is that it places the full risk of performance on the drilling contractor and therefore, the cost of assuming these risks is high. The day rate contract is perhaps the most commonly used, and is often seen as an IADC (International Association of Drilling Contractors) contract form that is used both as a bid request and contract. This approach establishes rates that are based on operational days plus mobilization/demobilization and materials. Inherent in this type of contract is the understanding that the drilling contractor is operating under the direction of the client. A footage contract will base the cost on the footage drilled. This type of contract is commonly used by the mining industry; however, it is less appropriate in scientific drilling where scientists may wish to suspend operations while measurements are made in the hole. It is also common to see a combination of the day rate and footage contract where the contractor requires a base price per day plus a rate per foot drilled. In any case, the bid documents must be carefully constructed and fit the purposes of the project.

For large projects, it is often desirable to schedule a site visit for prospective drilling operators. This visit should be held at the drill site and should familiarize contractors with local conditions. It will also serve to clarify any questions prospective drilling contractors may have concerning the RFP.

Following submission of proposals by drilling contractors, the PIs and the drilling engineer need to jointly review the offerings and choose a contractor. Federal guidelines suggest that the low-cost bid should receive the award. However, in the drilling business, the low-bid may prove more expensive in the long run. At this point, it is often appropriate for the drilling engineer to visit rigs that were offered in the proposals. The condition of the rig and support equipment will be a critical factor in the success of the drilling project.

PIs should use their drilling engineer to follow the general contractor's decisions on selection and management of specific subcontractors. In many cases the PIs may have a better understanding of the availability of specific subcontractor services in the drilling locality than the drilling contractor, and should make sure that the general contractor knows of all available options for controlling costs while maintaining quality.

Final drilling implementation and workshop

Shortly before drilling is to commence, a kickoff meeting of PIs and other key on-site science personnel (especially downhole experiment personnel) and the drilling contractor should be held to finalize the duty schedules for the drilling team and onsite science team. PIs should organize a website to provide daily reports and data to key parties not participating in onsite activities. It may be advisable to organize the website in such a way as to limit access to some areas to team members needing to see sensitive information.

Logistics and Project Execution

Logistical Considerations

Depending on the size of a drilling project and its location, logistical considerations can dominate the operations stage. Often, some or all of the logistics are handled by the PIs because of their knowledge of the local environment. However, it may be cost-effective to hire a logistics coordinator, particularly when operating overseas where local customs and language are factors or where there are a large number of personnel onsite (it is not uncommon for science plus drilling crews to number more than 20 persons). The science team needs to remember that the drill crews and drilling supervisor are hired to run the drilling operation, not logistics.

Appendix 3 is a generalized logistics checklist for the items that need to be considered for effectively running a drilling operation. These are also important cost components for budgeting, so they should also be considered when budgeting for the drilling operations.

There is a great deal of work that must be done prior to the drilling crews and equipment arriving at the project area. This includes permitting, site preparation, acquiring local labor, arranging for accommodation and food, *etc*. In addition, it is important to assess the local availability of supplies and services (machine shops, welding). In remote areas, it is advisable to bring a good inventory of spare parts and consumables rather than try to find them locally.

Permitting needs to be addressed far in advance of the drilling operations. The permits required, and the procedures for their acquisition are determined locally, and visits to regulatory agencies well in advance of drilling are recommended. The PIs are often in a good position to acquire permits since they have experience in the area. In addition to environmental permits, it is necessary to determine whether crews will require work permits.

Mobilization and demobilization of the drilling equipment will require outside assistance in most cases. For international projects this would include a shipping agent who will handle the formalities at the port of entry including customs clearance. Trucks will be required to move equipment to the drill site and a crane and forklift may be required to unload and assemble the drilling equipment.

Security is an important consideration both to prevent equipment and supplies from being stolen and to reduce the likelihood of bystanders being injured. All equipment should be stored in locked containers when not in use. During periods when the drilling operations are shut down, the project team needs to consider hiring guards for equipment and supplies.

During the drilling operations, it may be necessary to hire a person who is dedicated to handling the logistics of the operation. This is particularly true for lake drilling where the science and drilling crews are not able to easily leave the drill site. In these circumstances, it is necessary to have good communications between the drill rig and shore. The duties envisioned for a logistics coordinator may include arranging for housing and meals, coordinating fuel delivery, trips for supplies and personnel, communications, arranging for water delivery and interaction with the local population.

Site Safety Review

For many projects a pollution prevention and safety review will take place prior to the initiation of drilling operations. This outside panel will evaluate the overall project and make recommendations concerning potential drilling hazards. The drilling operator will have final authority on rig safety. The general contractor will be responsible for overall site safety.

Public Outreach and Publicity

Scientific drilling projects will attract a great deal of attention from the local population. This is an opportunity to showcase work and establish a positive impression. Tours at some sites have been sufficiently popular that they were conducted on a regular schedule. It is often advisable to have a supply of hard hats available for the visitors. Care must be taken to keep visitors out of areas where they can interfere with the drilling operations or be injured.

Standardization of Supplies and Consumables

PIs should attempt to standardize supplies and consumables to be used by the science team prior to the drilling campaign. This and other points below can be efficiently coordinated through the Chief Scientist, who might be one of the PIs or another well-organized person who is very familiar with all aspects of the science operation. PIs should seek advice on use of supplies, which may be standardized throughout their scientific community, especially when it will impact downstream core handling and storage. For example, the LacCore curatorial staff can advise lake-drilling project PIs on specific supplies that have proven effective in past lake drilling campaigns. For lake-drilling projects, experienced curators may be available to participate in the drilling project.

Standardization of core handling, storage and shipping

A detailed plan for core handling, storage and shipping must be prepared and budgeted as part of the project planning document. PIs should consult closely with all anticipated users of the core materials to insure that core handling does not violate particular sampling and/or quality assurance protocols important to individual team members' efforts.

Onsite training

Since science teams often have little experience in drilling operations, it is advantageous to schedule onsite training during an earlier project. This allows drilling proponents to spend several days on site acquiring hands-on experience with drilling and sample handling activities. ICDP has, in the past, sponsored such workshops.

Onsite Management of Drilling Operations

Management of drilling operations

PIs and drilling operators should insure that the drilling supervisor is present during mobilization/demobilization and drilling and geophysical logging activities, to serve as an interface between the science and drilling teams. This is critical for success because of the limited understanding each team has of the other's activities and the great potential for misunderstandings.

The chief scientist, as day-to-day manager of the onsite science team, needs to remain abreast of all developments occurring in the drilling operation, including scientific, engineering, and logistical issues. This is best accomplished by having a regularly scheduled meeting of the chief scientist, drilling supervisor, tool pusher and any other logistics coordinators during each operational day to review the past 24 hours progress and plan for the next day.

Site Safety

Ensuring site safety is a primary responsibility of the general contractor and the head of that team will always have the final say on "go/no go" decisions vis-à-vis drilling. The drilling contractor and the PIs should organize emergency drills prior to the start of operations, including assembly points, evacuation plans, emergency contact information (and location of such information on site) and immediate response. Onsite team members who arrive after the start of drilling should also go through these briefings and exercises. It is very strongly recommended that at least one (and preferably more) members of the onsite team have emergency medical training such as CPR and First-Aid.

The drilling operator will have established safety policies and should be able to give the science team a written safety plan. The drillers will commonly hold a safety meeting at the start of each shift. The science team should keep the numbers of their personnel around the drilling equipment to a minimum.

Access to information and samples and team communication

PIs should develop a uniform policy governing information and samples to reduce the likelihood of misunderstanding among participants. In the past, relationships between team members of some drilling projects have been severely strained by inadequate understanding of who will have access to what information and/or samples at the time of drilling. Timely dissemination of information to team members is essential both for science and team morale purposes. A website that is updated daily is an effective means for disseminating information to the scientific team.

Deviations from the drilling plan

It is not uncommon that a drilling plan will need to be revised during the course of operations, as a result of budget, weather, safety or science considerations. Ideally, alternate sites for drilling or alternate strategies for the same site will have already been anticipated in the drilling plan, and these alternatives will themselves have been presented to a safety and environmental panel for review. However, even with such alternatives in hand it often becomes necessary to make further changes to the drilling plan. When this occurs, it is important that the PIs have established a mechanism for smoothly making such decisions. A chain of command should be defined in terms of the scientific decisions on the suitability of the alternate plan. This is particularly important in cases where all PIs are not on site when decisions are being made. PIs should also try to make prior arrangements with their safety and environmental review panel for on-the-fly opinions of the advisability of alternative plans. PIs should also be aware that deviations and/or addition of last-minute experimenters and add-on science may be restricted by their funding agency; they are advised to discuss this extensively with their program officer in advance of drilling. As always, the final decision to proceed with a particular site must rest with the drilling operator, who is taking overall responsibility for the safety of the team.

Unknowables

PIs, the drilling supervisor, and drilling operators should always make allowances for the possibility of unforeseen developments during drilling. Particular attention should be put on planning for succession/change in PIs, schedule changes, legal liability issues and environmental issues. Also, it is standard practice in the drilling industry that the project is responsible for any tools lost or damaged downhole (below the keel in offshore operations). The loss of equipment will have an adverse budget consequence at any time during the project; however, it is particularly difficult when it comes in the latter parts of a project when the budgets are depleted. Although it is not possible to be prescriptive here, PIs should consider these points carefully in advance and HAVE A PLAN.

Post-Drilling Considerations

As soon as drilling is completed, the important tasks of data management, sample distribution, hole use, monitoring; and completion come to the fore. PIs should anticipate these activities in their drilling plans as appropriate. It is particularly important that post-drilling core shipping, handling and archiving plans be established in advance, and that contingency plans be considered.

As soon as possible, there should be a symposium on initial results, probably in conjunction with a regularly scheduled national or international meeting. PIs should strongly consider announcing their initial results in an appropriate science news venue, such as *EOS*. Later, the end of the sample moratorium period is a good time for a symposium or workshop to discuss and summarize results and introduce new scientists to research opportunities.

Following the end of the sample and data moratorium, all aspects of the project are open to participation through normal funding channels. In consideration of their time and effort invested in the drilling program, and for the broader interests of community support for continental drilling, PIs are urged to submit their results for publication in a timely fashion. Given the large public investment required for scientific drilling projects, PIs should make a point of disseminating their results widely. This includes peer-reviewed publications, websites, making materials accessible to educators, and by presenting results at colleges and universities.

Acknowledgments

As a professional courtesy, the drilling operator should be acknowledged in publications on the project results.

References

Zoback, M.D., Elders, W. A., Van Schmus, W. R. and Younker, L., 1988, The role of continental scientific drilling in modern earth sciences scientific rationale and plan for the 1990's, Stanford University, 151 pp.

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APPENDICES

APPENDIX 1

Roles and Responsibilities in a Scientific Drilling Project

Principal Investigators (PIs)

Key individuals that are the scientific and management leaders of the project. Normally, there are 1 to 4 PIs who decide among themselves their relative roles. Responsibilities include the following.

- Raise funds
- Interface with funding agencies
- Act as spokesperson to the scientific community and the public
- Establish the proposal writing team
- Write the proposal
- Facilitate logistics
- Obtain permits
- Establish onsite scientific staffing
- Establish subcontracts
- Maintain communications with Co-PIs
- Carry out the essential science
- Monitor budget and adjusting plans as necessary

Co-Principal Investigators (Co-PIs)

Individuals responsible for specific scientific components of the project. Their responsibilities include the following.

- Aid PIs in writing proposals
- Acquire funding for their scientific studies
- Carry out specific scientific investigations

Chief Scientist(s)
(Onsite Science Manager)

Responsible for onsite management of the drilling project and making daily decisions. Ideally, this role should be served by one of the PIs. The responsibilities include:

- Interface between the onsite science team and the drilling team
- Make daily decisions relating to the conduct of the drilling activities
- Manage the onsite science activities including sample handling and data collection
- Provide any needed logistical assistance to the drilling personnel
- Be a spokesperson to the public, local officials and press
- Monitor the onsite science budget

General Contractor

Hired by the PIs to handle the contracting and administrative aspects of the project. This role may be filled by a university, nonprofit (DOSECC or JOI) or a commercial firm.

- Receive money from funding agencies or universities
- Procure supplies and services through competitive bids
- Establish subcontracts for the performance of drilling and scientific operations
- Site Safety
- Handle expenses in accordance with federal guidelines
- Document receipts and performance of supplies/services
- Issue payment to subcontractors/vendors
- Monitor expenditure of the overall budget

Drilling Engineer

A key individual who works for the science team.

- Works with the PIs to formulate an initial drilling plan and budget that accommodates the scientific objectives of the project
- Determines the scope of supply to be requested from the drilling contractor and the additional subcontractors that will be required by the project
- Aids the PIs in formulating a Request for Proposals (RFP) for a commercial drilling contractor
- Assembles a list of qualified bidders to receive the RFP.
- Organize site visits for potential bidders

- Aid PIs in reviewing drilling proposals and negotiating with potential contractors

Drilling Supervisor

Designated by the PIs to be their onsite representative during the drilling operations. This role incorporates the responsibilities of a "company man" in petroleum drilling. This may be the same person who serves as the drilling engineer.

- Works with PIs and selected drilling operator to expedite mobilization to the drill site
- Serves as the onsite drilling manager on behalf of the PIs; responsibilities include interface with the drilling contractor, approval of daily drilling reports, monitoring of supplies utilized and cost control
- Interacts with the Chief Scientist to schedule sampling, logging and downhole experiments

Drilling Contractor

The company that performs drilling operations.

- Supply drilling equipment and experienced personnel
- Report on the progress of drilling operations
- Responsible for Rig Safety

Tool Pusher

The drilling contractor's principal representative on the drill site. The pusher will normally live at the drill site during operations. The responsibilities of this person are listed as follows.

- Management of the contractor's drilling crews. Drilling will normally have two shifts that work 12 hours each
- Serve as the principal point of contact with the client (PIs, Chief Scientist, Drilling Supervisor)

APPENDIX 2

Scientific Drilling - Planning Checklist

		Responsibility
Management	• Project management	
	• Team leadership	
	• On-site management	
	• Budget control	
	• Reporting procedures	
Drilling and Casing	• Depths, Diameters, etc.	
	• Directional issues?	
	• Mud chemistry, weight?	
	• BOP/Safety	
	• Use of liners, temporary casings	
Coring	• Depths, diameters, technique	
	• Special handling procedures	
Logging	• Commercial logging	
	• Other (such as ICDP)	
	• Specialty logs	
	• Depths	
Other Downhole Measurements	• Fluid Sampling/Well Tests/Hydrofrac	
	• Geophysical measurements (VSP, etc.)	
Long Term Use of Holes	• Observatory?	
	• Plug and abandon	
On-site Sample Handling	• Planned measurements (Photographs)	
	• Special handling procedures	
	• Short term disposition	
Long Term Sample Disposition	• Sample handling	
	• Permanent repository	
Data Products	• Real time data (DIS?)	
	• Log & sample database	
	• Publication strategy	

APPENDIX 3

Scientific Drilling - Logistics Checklist

		Responsibility	Cost
Communications	Cell Phones		
	Satellite Phone		
	Email		
	Web Access		
Housing	Hotel		
	Apartments		
	Travel Trailer		
	Ship-based Accommodations		
Meals	Cook		
	Food Supplies		
	Water		
Transportation	Vehicles		
	Crews from Airport		
	Daily Commute to Rig		
	Site-to-site moves		
	Mobilization/Demobilization		
	Supplies		
	Courier Services		
	Customs		
	Freight Expediters		
Money	Bank		
	ATM		
	Credit Cards		
Drilling Supplies/Services	Diesel		
	Gasoline		
	Mud Supplies		
	Mud Disposal		
	Cement		
	Crane		
	Forklift		
	Oil and Lubricants		
	Machine Shop		
	Welding		
Sanitation	Latrines		
	Trash Removal		
	Hazardous Material Disposal		
	Hazardous material containment		

APPENDIX 3 (CONTINUED)

		Responsibility	Cost
Support Facilities	Offices		
	Laboratories		
	Container Storage		
	Security		
	Water		
	Electricity		
Local Employees	Payment		
	Work Rules		
Health and Safety	Hospital		
	Ambulance		
	Fire Department		
	Safety Training (CPR/First Aid)		
	Site Emergency Plan		
	Evacuation Plan		
	Health Briefing/Inoculations		
Permits and Licenses	Work Permits		
	Drilling Permits		
	Air Quality Permits		
	Land/Water Use		

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