Potential for Collaboration between the Norwegian offshore oil- and gas industry and JPL/NASA:

How to Set up and Implement such a Collaboration

March 2, 2010

by
Dr. Knut I. Øxnevad
SIMTANO™

with
contributing partners

ARENA IO (Martin Sigmundstad)
FMC Technologies (Sigurd Moe)
Jet Propulsion Laboratory – JPL (Issa Nesnas, Khaled Ali)
Kongsberg Maritime (Bjørn Jalving)
Norsk Forening for Automatisering – NFA (Lars Annfinn Ekornsœter)
Statoil (Brage Wårheim Johansen, Cato Wille)

EXECUTIVE SUMMARY

There are two steps to setting up a technology collaboration with NASA/JPL. The first step is to find areas of common interest, and the second step is to look at the practical steps of setting up such collaboration. Step 2 has capsized many good intentions of collaboration. In this study great effort was, therefore, placed on thoroughly understanding, documenting, and testing all the required steps.

In an on-line survey conducted in Norway, the majority of the respondents showed interest for support from the space industry in developing technologies for surface and mobile subsea systems. Special interest was shown for technologies related to process, pumps and valves, and robotics/automation/autonomy/machine control and simulation functions.

Likewise, the majority of the respondents envisioned that they had technologies that could be relevant for subsurface and fixed surface systems in the space sector. Here, technologies related to drill, guidance, navigation & control, power, robotics/automation/autonomy/machine control, and simulations functions were emphasized.

Robotics/automation/autonomy/machine control and simulations point themselves out as the areas where the respondents see they both could benefit from support from the space industry, and believe they have expertise that could benefit the same industry.

Robotics and automation is an area that JPL strongly emphasizes. There should therefore be potential for some mutually beneficially two-way collaboration in this area.

Systems and electronics developed for extreme environments and instruments covering all wavelengths are other areas at JPL with potential applications in the oil and gas industry.

The vision of this study was to define a mechanism for collaboration that would make it possible for both small and large energy related companies in Norway to collaborate with JPL/NASA. Any support/work contract that JPL enters into with a foreign entity has to be approved by JPL and then NASA HQ, possibly the State Department. This takes time, between 4 and 12 months. Efforts have been done in this study to find ways to shorten the approval time. So far, no perfect solution has been found. Further work in this area is recommended as a follow-up to this study.

When entering into a contract with JPL/NASA, and after having signed the Space Act Agreement, a company will receive a license for internal use of the developed technology. Commercial use of the developed technologies and related royalties has to be negotiated separately with California Institute of Technology (Caltech).

The NASA/JPL system requires that companies utilizing the support of NASA/JPL pay upfront for the work. Payments will be made to NASA HQ, which will then send the money to JPL. The latter can take up to 2 months. No work can start at JPL before funds are received.

To test all the steps discussed above, the Steering Committee, after a careful evaluation, agreed to work with Seabed Rig to help them set up a technology development project with JPL/NASA. Initially this was planned started in March 2010. But, after a number of internal Seabed Rig reviews this fall, it was decided to postpone the planned start to October/November, 2010. Both ARENA IO and SIMTANO will support Seabed Rig in moving this collaboration forward.

A potential workshop to discuss areas of collaboration has been suggested for the May-June time frame. The idea is to arrange the workshop at a hotel in Pasadena, CA and include tours to the JPL facilities and laboratories.

JPL and NASA makes it possible for companies they are supporting to pay for and select researchers for their own projects. This would make it possible for highly skilled Norwegian researchers to work on Norwegian funded development projects at JPL/NASA. These researchers would be able to show what Norwegian companies and research organizations have to offer, and help open up for two-way collaboration between the Norwegian Energy Industry and JPL/NASA. This will take time.

It is important that Norwegian organizations (ARENA IO, the Norwegian Research Council, Statoil, FMC, etc.) play active roles in making sure that the selected researchers are kept up to date on relevant research going on in Norway, and keep close contact with them while they are at JPL, as well as afterwards.

Hopefully the information provided in this report will encourage the development of exciting technology collaboration projects between energy related organizations in Norway and NASA/JPL.

To move forward, it is essential that a project be selected (e.g SeaBed Rig) and funding provided. The Norwegian side should make every effort to make this happen.

The study was managed by Knut I. Øxnevad, SIMTANO, and supported by a Steering Committee consisting of members from ARENA IO (Martin Sigmundstad), FMC (Sigurd Moe), JPL (Issa Nesnas. Khaled Ali), Kongsberg Maritime (Bjørn Jalving), Norsk Forening for Automatisering – NFA (Lars Annfinn Ekornsœter), Norwegian Space Centre (Geir Hovmork), SIMTANO (Knut I. Øxnevad), Statoil (Brage Wårheim Johansen, Cato Wille). The Steering Committee met 6 times via GoToMeeting.

Knut I. Øxnevad, proposal and study manager, worked at JPL for nearly 10 ten years (1996-2005) and has since 2004 worked as a consultant with the Norwegian oil- and gas sector. He knows both sectors well. He authored an article about the parallels between the space and offshore oil- and gas sectors in 1992. Most of the suggestions posed to the offshore oil- and gas industry are still relevant today. The article is attached.

Funding for the study was provided by Innovation Norway (NOK200K), Statoil (NOK50K), Kongsberg Martime (NOK50K), FMC (NOK50K), JPL (NOK70K, in-kind), and SIMTANO (NOK70K, in kind).

TABLE OF CONTENTS

TABLE OF FIGURES

1. INTRODUCTION

Numerous parallels exist between offshore oil- and gas technologies, especially subsea; and space related technologies. Being able to utilize these parallels could be of great benefit to both large and small offshore oil- and gas related companies and organizations in Norway, as well as the space communities both in Europe and in the United States.

A number of initiatives have already been taken towards the European Space Agency, and limited communication has also started with the Lyndon B. Johnson Space Center in Houston.

This report discusses how to set up and implement a technology collaboration effort between Norwegian oil- and gas companies/organizations and the Jet Propulsion Laboratory - JPL, California Institute of Technology.

The Norwegian offshore oil and gas industry has already shown interest for such collaboration. For example, a senior delegation from Statoil visited NASA HQ, JPL, and other NASA centers in September 2004.

JPL is interested in utilizing their technologies in none space related areas. They are already working with the US Navy on developing subsurface vehicles and the mining industry for developing inspection robots. They see interesting opportunities arising from working with the offshore oil- and gas industry.

As a first step, it is envisioned that JPL will carry out research projects for and funded by the Norwegian offshore oil- and gas sector. In other words raise the technology level in the Norwegian offshore oil- and gas Industry through e.g. the use of technologies similar to those used today by the Mars rovers, Spirit and Opportunity.

Next, in step 2, it is envisioned that one will seek out areas where the current Norwegian offshore oil- and gas technology may be applicable for NASA/JPL's space projects. Further, one will consider joint technology development projects that would benefit both JPL/NASA and the Norwegian offshore oil- and gas sector.

Focus of this report is on the first step, but issues helping prepare for step 2 are being addressed. For example, which technologies does the Norwegian Energy see they can offer the space industry. However, the practical steps for setting up two-way collaboration as addressed in step 2, are defined as being outside the scope of this report.

The objective of the study leading to this report was therefore defined as follows:

1. Investigate how to bring the Norwegian offshore oil- and gas technology to the next level through joint technology development efforts with the Jet Propulsion Laboratory – JPL, California Institute of Technology (Appendices A and B). The ambition is to make it possible for large and small Norwegian oil- and gas related companies and organizations to take part in and benefit from these technology development efforts.

To meet this objective, a set of study activities were defined. Each of these study activities is discussed in the chapters of this report - one chapter per study activity. However, during the study it was decided to de-emphasize the following study activities:

1. Define suggested procedures for JPL and Norwegian companies to work together. Focus will be on technology projects that JPL is conducting for Norwegian companies. This will include frequency of reviews, effective work processes for dealing with the time difference.
2. Define JPL relevant technology development projects that are of special interest to the Norwegian offshore oil- and gas sector that together amounts to some NOK 20-35 mill ($3-5 mill). It is recommended that over time this level be reached to get the required attention from JPL.
3. Suggest a two-year technology collaboration schedule

Brief summaries of the 9 chapters in the report are provided below:

- **Chapter 2, Norwegian offshore oil- and gas sector: Technology needs, and potential technology offerings to the space industry:** The discussion here focuses on which technologies (hardware and software) and technology development projects that are of special interest to the Norwegian offshore oil- and gas sector, and which of their technologies they see could be of interest to the space sector.

- **Chapter 3, JPL: Technology needs, and potential technology offerings to the Norwegian offshore oil- and gas industry:** In this chapter the focus is on what technologies (software and hardware) JPL may provide, and on which technologies the Norwegian offshore- oil and gas sector have, that JPL sees could potentially be of interest to them.

- **Chapter 4, Organization and Mechanisms for Collaboration:** Mechanisms for making it possible for both ARENA size companies and larger companies such as Statoil and FMC to work effectively with JPL are discussed. Suggested solutions are provided.

- **Chapter 5, Legal implications: ITAR, licensing and IP:** The legal implications of technology development efforts between JPL and Norwegian companies are addressed, including United States ITAR, and licensing- and Intellectual property.

- **Chapter 6, Flow of funds:** The most effective way to flow funds from Norwegian companies to JPL is being addressed and solutions provided.

- **Chapter 7, Initial technology development project with JPL:** The selected Seabed Rig technology development project is discussed. The plan is to start the project in the October/November, 2010.

- **Chapter 8, JPL Workshop: Date and Agenda:** Date and agenda items for a potential joint workshop between the Norwegian Energy companies and JPL/NASA are discussed. May/June, 2010 is suggested

- **Chapter 9, JPL technology grant to a Norwegian postdoctoral researcher:** The mechanisms for how to invite highly qualified researchers to JPL/NASA to be part of the selected technology collaboration projects are addressed.

- **Chapter 10, Topics for further study:** Suggested topics for further study are discussed.

- **Chapter 11, Organization:** The study organization is presented

- **Chapter 12, Acknowledgements:** The people who made special contributions to the study are being recognized.

2. Norwegian offshore oil- and gas sector: Technology needs, and potential technology offerings to the space industry

It was decided to use an online survey (www.surveyshare.com) to capture which technology development projects that are of special interest to the Norwegian offshore oil and gas sector (**NEEDS**), and which offshore oil and gas technologies this sector see could be of interest to the space sector (**OFFERINGS**). The participants were asked to provide only publicly available information.

Completing the survey was estimated to take between 3 and 7 minutes. The survey was sent to 194 selected companies. 17 of these companies responded to the survey. The survey, therefore, is not statistically significant. The calculated percentage responses show only how the surveyed group responded, and should only be used as indicator for how the Norwegian oil and industry in general may have responded to these questions. The survey was programmed to allow for extensive cross-correlation between the responses.

In the first part of the survey, the respondents were asked to provide, name of company, URL, contact person, e-mail of contact, number of employees, operating revenue, and industry category affiliation.

47% of the respondents represent organizations with 10-100 employees. The remaining represent organizations with these number of employees: 1-10 (12%), 100-500 (12%), 500-1000 (12%), 1000-3000 (6%), and 3000-6000 (12%).

18% of the respondents are in organizations with operating revenues (NOK) of either 1-10 mill, 50-100 mill, or 100-300 mill; 12% in companies with operating revenues of either 10-50 mill, 600-1000 mill, or above 5000 mill; and 6% in companies with operating revenues of either 300-600 mill or 1000-5000 mill.

24% of the respondents are in the visualization industry, 18% in the Robotics/Automation/Autonomy, and 12% are in the Drilling/Well Services and Tools industry. The rest are distributed as shown in **Figure 1: Respondents Industry Affiliation**

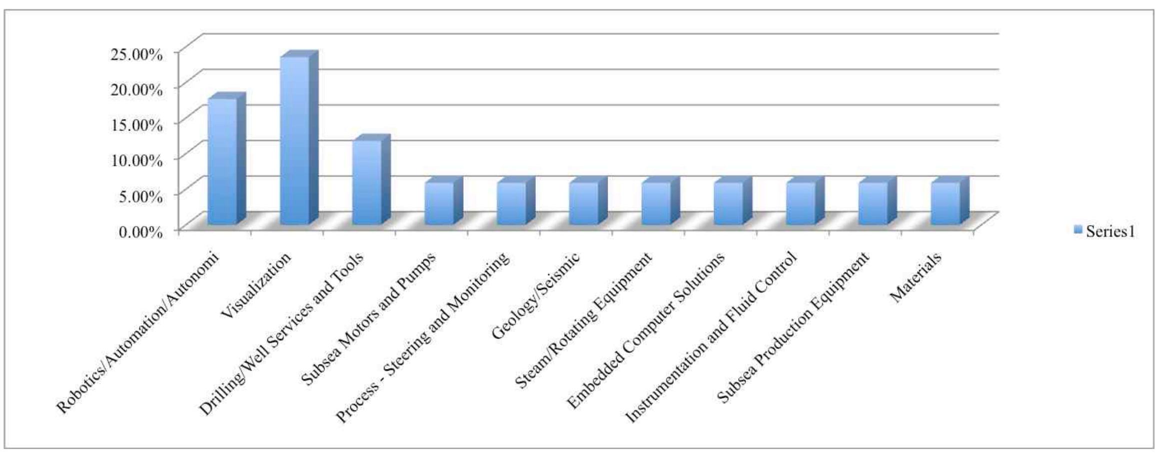

Figure 1: Respondents Industry Affiliation

To capture the central characteristics of the technology development **NEEDS** and **OFFERINGS**, the respondents were asked to specify where they saw the technology was going to be used and what function(s) it would fill. Only one **location** could be selected at the time. But within each **location** many **functions** could be selected. An effort was made to make the **locations** and the **functions** in the technology development **NEEDS** (oil and gas) and **OFFERINGS** (space) very similar. The respondents were also given an opportunity to provide a 3 to 5 line description of the technology in question.

For NEEDS (oil and gas) the following **locations** were defined: Surface, Subsurface, Subsea (Mobile), and Subsea (Fixed). Correspondingly, the following **functions** were selected: Cost and schedule, Drill, Economic analysis, Electrical, Electronics, Geosteering, Guidance and Navigation, Hydraulics, Instrumentation/Payload, Manipulators, Material, Mechanical, Power, Process, Project management, Propulsion, Pumps and Valves, Risk Analysis, Robotics/Automation/Autonomy/Machine Control, Simulations, Telecommunication, Telemetry, Thermal, and Other. The 17 respondents provided in total 132 Responses.

For **Offerings (Space)** the following **locations** were defined: Subsurface, Ascent-/Descent Vehicles, Space Station, Satellites, Space Probes, Transfer Vehicles, Launcher, Surface (Fixed), Surface (Mobile), and Surface (Lander). Correspondingly, the following **functions** were selected: Cost and schedule, Drill, Electronics, GeoSteering, Guidance, Navigation and Control, Payload, Manipulators, Material, Mechanical, Power (Electrical), Project Management, Propulsion, Risk Analysis, Robotics/Automation/Autonomy/Machine Control, Separation Mechanisms (explosives, etc.), Simulations, Telecommunication, Telemetry, Thermal, and Other. The 17 respondents provided in total 100 responses.

For the **NEEDS** part, **42% of the technology development needs fell within Surface**, 11% within Subsurface, 23% within Subsea (mobile), and 24% within Subsea (fixed).

The respondents saw these technology development **NEEDS** mainly within the **Robotics/Automation/Autonomy/Machine Control (10%)**, **Process (9%), Robotics** Pumps and Valves (6%), and Simulations (6%) functions. For further details, see **Figure 2: NEEDS; Selected Functions**

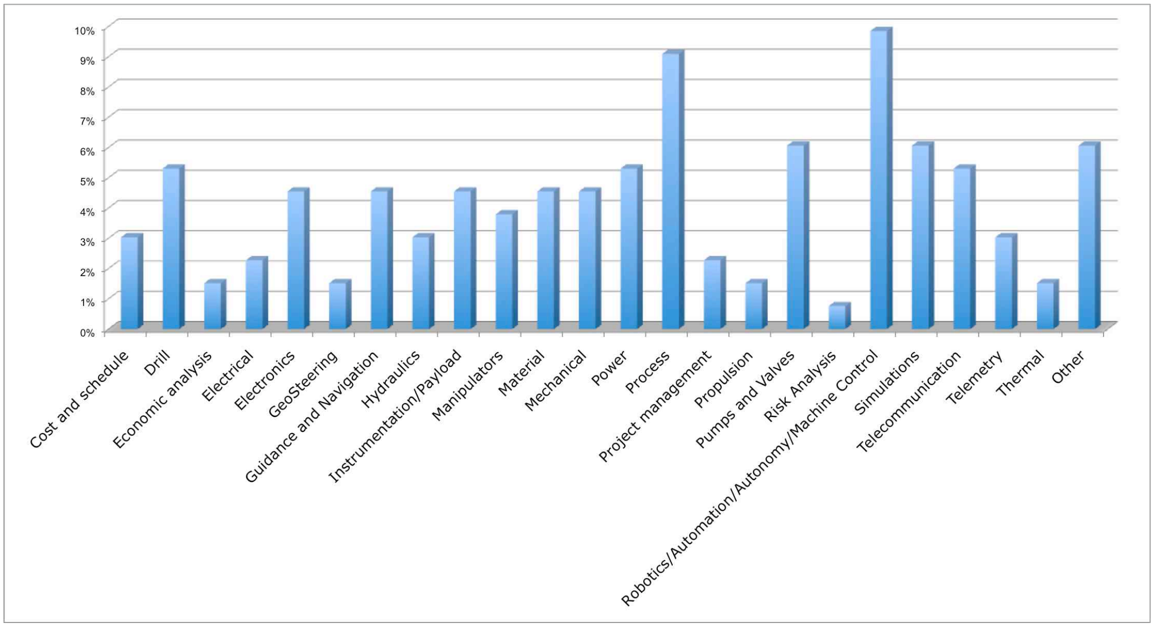

Figure 2: NEEDS; Selected Functions

Information about which technology development projects are of interest for which locations can also be provided. For example, within Surface, the respondents see technology development NEEDS mainly in Process (13%) and Robotics/Automation/Autonomy/Machine (11 %).

Some of the specific technology development **NEEDS** mentioned by the respondents were:

Multi-joint robots for inspection and maintenance; Subsea inspection with autonomous underwater vehicles; AUV: Development within autonomy, adaptive behavior and robotic operations; Precise positioning related to use of GNSS (Global Navigation Satellite System); Downhole instrumentation; Embedded, high temperature, rugged, low power electronics; Data collection and management; and advanced materials.

For the **OFFERINGS (Space)** part, **34% of the technology development offerings fell within Subsurface**, none within Ascent-/Descent Vehicles, 1% within Space Station, none within Satellites, 1% within Space Probes, 2% within Transfer Vehicles, 3% within Launchers, **49% within Surface (Fixed),** 10% within Surface (Mobile), and none within Surface (Lander).

The respondents saw these technology development **OFFERINGS** mainly within the **Robotics/Automation/Autonomy/Machine Control (12%)**, **Simulations (12%), Guidance,** Navigation and Control (8%), Drill (7%), Power (Electrical) (7%), functions. For further details, see **Figure 3: OFFERINGS; Selected Functions**.

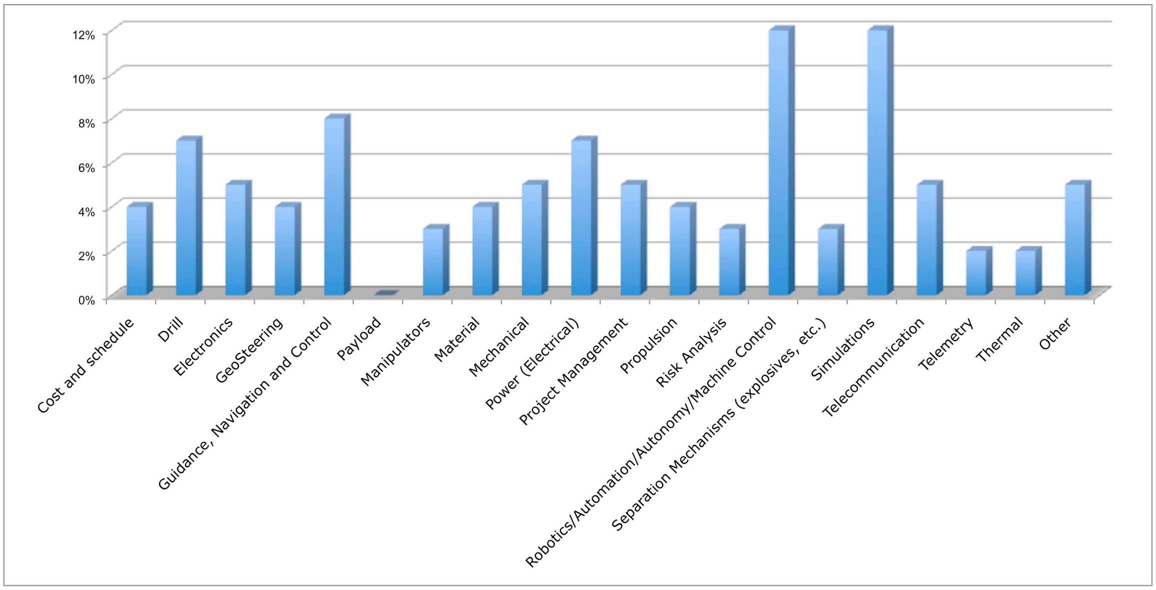

Figure 3: OFFERINGS; Selected Functions

Information about which technology OFFERINGS were of interest for which locations can also be provided. For example, within Subsurface, the respondents see themselves being able to provide technologies mainly for the Drill (21%) and Robotics/Automation/Autonomy/Machine (14%) functions.

Some of the specific technology development **OFFERINGS** mentioned by the respondents were:

Teleoperated systems and highly-articulated mobile platforms for inspection and maintenance; HUGIN AUV technology could be applied for space applications; Attitude sensors; and Embedded electronics

Conclusions

The majority of the technologies that the respondents want JPL/NASA support with **(NEEDS)** are within Surface, Subsea (Mobile), and Subsea (Fixed) locations; and are relevant for Process, Pumps and Valves, Robotics/Automation/Autonomy/ Machine Control, and Simulation functions.

Correspondingly, the majority of the technologies that the respondents want to **OFFER** to JPL/NASA are within Subsurface and Surface (fixed) locations; and are relevant for Drill, Guidance, Navigation and Control, Power (Electrical), Robotics/Automation/Autonomy/Machine Control, and Simulation functions.

Interestingly, a majority of the responses for both **NEEDS** and **OFFERINGS** emphasize technologies related to Robotics/Automation/Autonomy/Machine Control and Simulations. This indicates that there may be interesting opportunities for two-way collaboration in these areas.

3. JPL: Technology needs, and potential technology offerings to the Norwegian offshore oil- and gas industry

Information about which technologies are of special interest to the oil and gas industry was captured through review of presentations and statements from leading experts in the Society of Petroleum Engineers, representatives of the Steering Committee, and from other organizations. The results from the survey also provided valuable input.

This information was used as input to set up a list of which JPL/NASA technologies that are of special interest **(OFFERING)** to the Norwegian oil and gas industry. As part of this, the JPL website was reviewed thoroughly, and number of discussions were held with representatives from JPL/NASA.

In this chapter only the highlights will be provided. More details are given in referenced URL's and in Appendixes to this report.

Jet Propulsion Laboratory (http://www.jpl.nasa.gov), part of Caltech (Appendix B), has developed nearly all of National Astronautics and Space Administration's (NASA: Appendix C) outer planet missions. Among them the Viking missions to Mars, Cassini, and now lately the Mars rovers, Spirit and Opportunity (Ref. 1). JPL is regarded as one of the finest centers in the NASA system. It employs some 5200 engineers and scientist. A large percentage of these have doctorate degrees.

To be able to conduct these sophisticated missions, JPL has extensive technology development programs. Technology experts from some of these programs may be engaged, fee based and through JPL, to develop technologies for external organizations.

JPL's technology development program (Ref. 2) include the areas of Earth Sciences, Planetary Sciences, Astrophysics and Space Science, Exploration & Observational Systems, and Software & Computing Systems

Exploration & Observational Systems includes the following relevant areas, Robotics and Survivable Systems for Extreme Environments:

Robotics and Automation (covered by the Robotics and Software and Computing groups) support space, military, and other terrestrial applications. Examples of such applications are shown in **Figure 4: Military and Terrestrial Applications**. and **Figure 5: Space Applications**

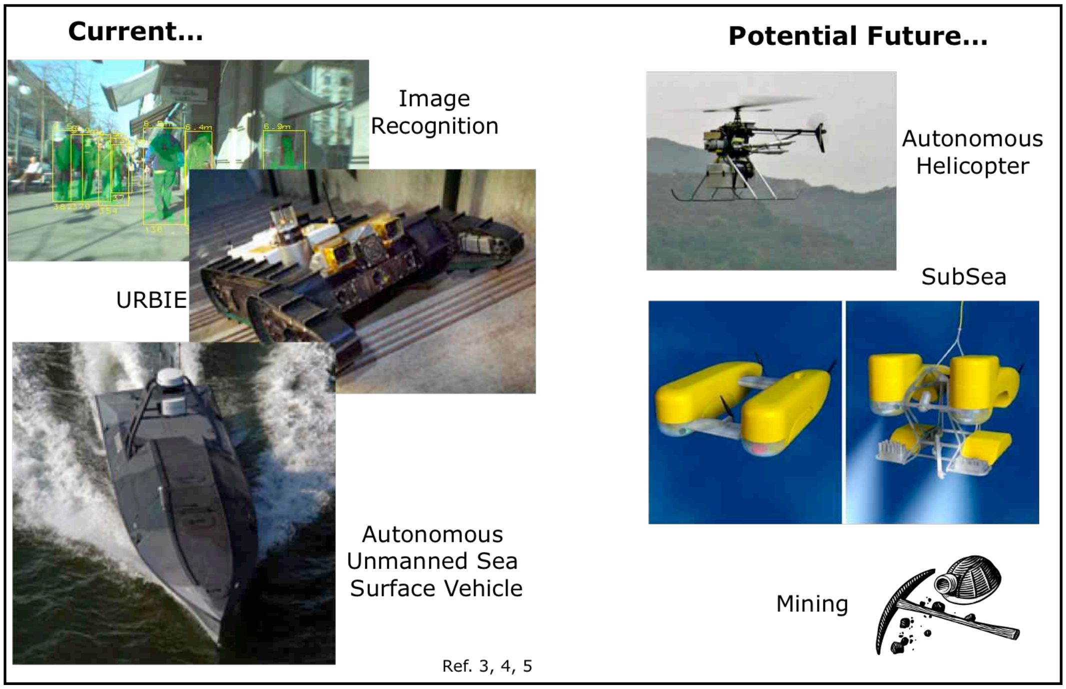

Figure 4: Military and Terrestrial Applications

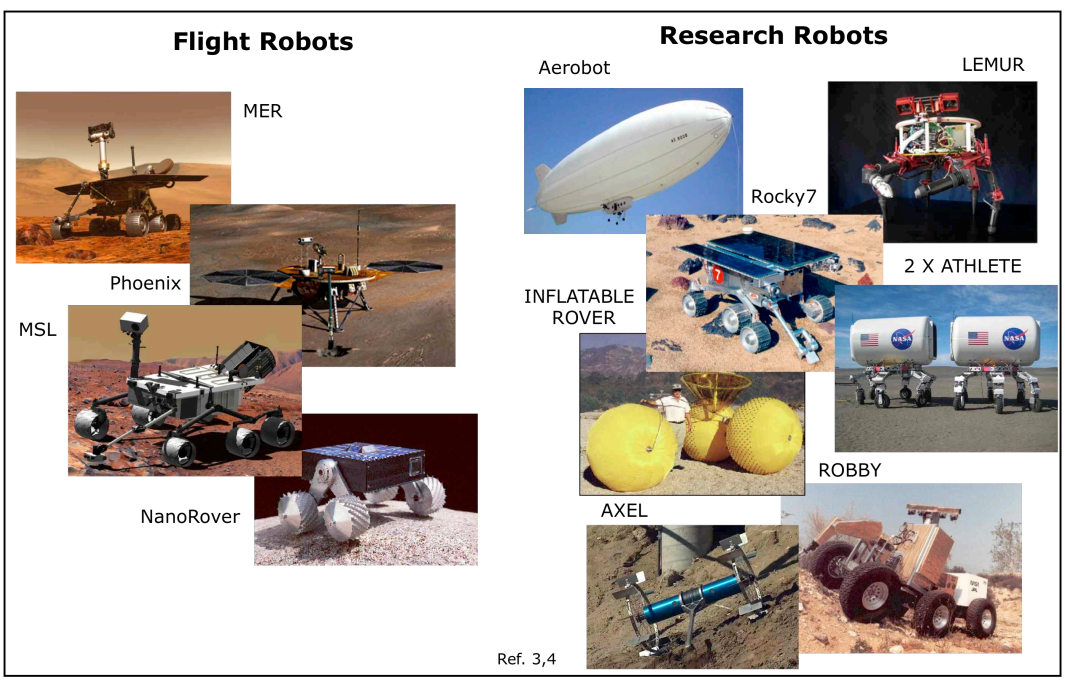

Figure 5: Space Applications

These organizations **OFFER** support in areas such as work terrain and path analysis (including collision avoidance), approach and instrument placement, sampling for analysis, rendezvous and docking, drilling, as well as user operations interfaces.

Their experts use, for example, the following software:

1. DARTS - A high-performance computational engine for flexible multibody dynamics
2. Dshell - A multi-mission simulation framework for real-time, hardware-in-the-loop spacecraft simulations
3. Dspace - A 3D graphics tool for real-time, closed-loop simulation visualization.
4. Hyperdrive – An immersive 3D simulation for rovers and their environment.
5. CLARAty, autonomous on-board control software.

These capabilities could be of interest to both subsea operations, subsurface work, and sophisticated surface installations.

The Extreme Environments group under Exploration & Observational Systems is tasked to develop high temperature systems for a Venus landing. Such a mission will require electronics and instruments that can withstand temperatures of 460°C and pressures of 90 bar. This type of systems could be relevant for High Temperature and Pressure oil and gas wells, as well as for enhanced geothermal wells.

JPL has extensive expertise in developing sophisticated light, power efficient, and miniaturized instruments for their various missions. These instruments cover all wavelengths and are both passive and active. The Advanced Instrumentation & Spectroscopy Group under Planetary Sciences covers work in this area. This expertise could be relevant as more use of advanced geosteering in the oil and gas industry is pushing for instruments with similar characteristics.

Other areas that JPL that can OFFER potential support are:

- Pizo-electric drills for up to 500°C, being developed for Venus and are at this point only developed for small and shallow holes (Ref. 8)

- Gravity Gradiometer, using atom interferometry for mapping underground features at great detail (Ref. 9)

- Hydrogen storage, the Metal Hydride Center of Excellence (MHCoE), find a material that can reversibly absorb and desorb hydrogen so that hydrogen powered cars become practical and affordable

Conclusions

JPL has special expertise within robotics and automation (including simulations) that they can OFFER the Norwegian oil and gas industry. At the same time, the Norwegian oil and gas industry may be able to offer JPL expertise within drilling technologies (e.g. geosteering), potentially also within control of subsea vehicles, and simulation experience gained within subsea and subsurface operations.

References

1.JPL (NASA): http://www.jpl.nasa.gov/missions/index.cfm?type=&MissionTheme='Earth'%20or%20MissionTheme='SolarSystem'%20or%20MissionTheme='StarsGalaxies'&LaunchSort=Desc

2.JPL (NASA): http://scienceandtechnology.jpl.nasa.gov/research/ResearchTopics/

3.JPL (NASA):http://scienceandtechnology.jpl.nasa.gov/research/ResearchTopics/topicdetails/?ID=59

4.JPL (NASA): http://robotics.jpl.nasa.gov

5.JPL (NASA): http://www-robotics.jpl.nasa.gov/applications/index.cfm

6.JPL (NASA): http://www-robotics.jpl.nasa.gov/systems/index.cfm

7.JPL (NASA): http://claraty.jpl.nasa.gov/man/overview/index.php

4. Organization and Mechanisms for Collaboration

Setting up an effective collaboration mechanism between companies in the Norwegian oil and gas industry and JPL that caters to ARENA size (small) and large (Statoil, FMC, etc.) companies, and that involves such a high number of companies that it becomes interesting for JPL, represents a number of challenges.

To find solutions that are acceptable to both parties, extensive discussions were held with selected representatives of the Steering Committee and from JPL. From the JPL side these discussions included JPL and Caltech lawyers, representatives from the JPL NASA Management Office (NMO) and the JPL Program Office dealing with external work.

During these discussions many models were suggested. The initial model was to use SIMTANO (Los Angeles) in combination with ARENA IO (Stavanger) as intermediaries. It came clear early that NASA would not accept such a solution. They would need to work directly with the company that they would do the work for. Instead NASA suggested that a consortium be set up in Norway that would represent all the companies wanting to work with JPL. All contracts would then be between JPL and the consortium. However the legal implications of setting up a consortium with a number of different companies in the consortium and having the consortium being legally responsible for the contracts with these companies made this a no-go.

Finally the model that it was agreed to pursue would make the contract set up directly between JPL/NASA and the Norwegian company in question. The challenge with this model is that it today takes NASA HQ between 4 and 12 months to approve a collaboration effort with a foreign company. Space related technologies are in export control terms regarded as military items. This is discussed in more detail in Chapter 5: Legal implications: ITAR, licensing and IP

On the Norwegian side, ARENA IO would provide support to the companies planning to enter into collaboration contracts with JPL. This support would include general information about, how to work with JPL/NASA and what capabilities JPL has, required contracts (Space Act Agreement, Royalty Agreement with Caltech), payments, how to involve Norwegian researchers in potential JPL projects. ARENA IO would also be able to provide general contractual support.

On the US, Los Angeles side, SIMTANO INC would provide support for the companies and their researchers while they are in the US. Such support would include technical expertise, detailed information about JPL and who to work with there, help with communicating with the home office, getting access to JPL, and help with accommodations.

The model is shown in **Figure 6: Organization and Mechanisms for Collaboration**

The selected model would further require that:

1. International Space Act Agreements be set up directly between NASA and the companies seeking to collaborate with NASA/JPL

2. Legal experts in Norway would work with Seabed Rig to help set up a "standard" International Space Act Agreement template. All Norwegian Companies seeking to collaborate with NASA/JPL would use this template as a basis.

3. Any Norwegian company seeking to work with NASA/JPL would have to accept the terms in the agreed to "standard" International Space Act Agreement.

4. It would be up to each company to negotiate expanded use of IP, royalty, and licensing arrangements directly with Caltech, and the technical and scheduling details of the NASA/JPL task plans.

5. NASA would seek to streamline and compress the International Space Act Agreement approval process for Norwegian Companies, given that all these companies will be using the same standard International Space Act Agreement

Efforts are being made to contact the right people at NASA HQ to investigate whether it is possible to streamline the approval process there.

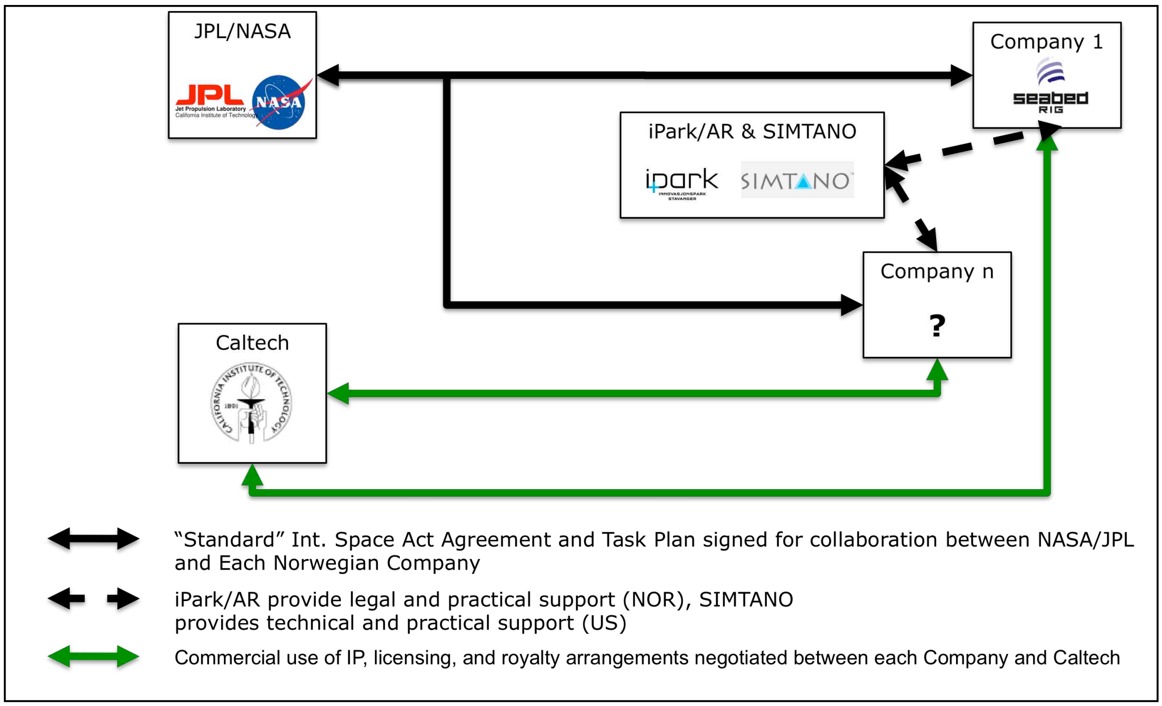

Figure 6: Organization and Mechanisms for Collaboration

Another alternative is to avoid the NASA HQ approval altogether. JPL is authorized to enter into agreements with domestic companies directly. Such a company could be a subsidiary of a Norwegian company. There are two issues with this solution. It would preclude ARENA sized companies with no subsidiary in the US from collaboration with JPL. Further, it would shift the burden of dealing with export controls over from NASA to the subsidiary of the Norwegian company. This may save time, but the subsidiary still will have to go through the often lengthy export control approval process.

The Steering Committee selected a Seabed Rig project to test out the model to better understand the required steps and to seek out areas for potential improvement. Hopefully this would make the approval process at NASA HQ for the next Norwegian project less time consuming. The Seabed Rig project is discussed in Chapter 7, Initial technology development project for JPL.

Conclusions

Military and most space technologies are subject to strict US export regulations. The approval process for projects, involving these technologies, will therefore be extensive and time consuming. Yet, at the same time, companies deal with these regulations every day. To involve the smaller companies in the oil and gas industry in Norway, going through NASA HQ and accepting the 4-12 month approval process, seems to be the only option. Larger companies with a subsidiary in the US may consider working directly with JPL and then deal with the export control issues themselves.

5. Legal implications: ITAR, licensing and IP

Foreign entities collaborating with NASA/JPL are subject to export controls (Department of State or Department of Commerce), the Space Act Agreement (NASA), and the Royalty and IP requirements from Caltech. These three are discussed in this chapter.

Export controls can be defined as U.S. Government regulations that govern the export of strategic technologies, equipment, hardware, software, and technical support to Foreign Entities.

U.S. Department of Commerce, Bureau of Industry & Security (BIS) (Ref. 1) handles Export Administration Regulations (EAR). EAR controls items on the Commerce Control List (CCL) that have commercial or dual-use (military/strategic and commercial) applications, for example, high performance computers and encryption software.

U.S. Department of State handles the International Traffic in Arms Regulations (ITAR). ITAR controls Defense Articles & Defense Services (technical data and know-how) found in the U.S. Munitions List (USML) (Ref. 2). The list includes, category XV - spacecraft systems, science instruments on spacecraft & associated equipment and software, XX - Submersible Vessels, Oceanographic and Assoc. Equipment.

In other words, potential technology development projects with JPL/NASA are subject to ITAR and approval by the Department of State. This process is lengthy, but not at all impossible. And, there are exceptions, for example, space related software that has not been flown is typically not subject to ITAR.

The Space Act Agreement is set up to protect the technologies and IP developed with US tax payers money, and make sure that the invested money is used to the benefit of the same tax payers.

Therefore, a company paying JPL/NASA to do development work will not become the owner of the Intellectual Property Rights of the developed technology (hardware or software). Instead, the company will receive “a royalty-free, non-exclusive, non-commercial, internal use license on behalf of the U.S. Government.”

If the company wants to obtain a commercial and/or exclusive license, this needs to be negotiated with Caltech’s Office of Technology. Typically royalty fees are in the 3-5% range.

Conclusions

Development work at JPL/NASA paid for by a foreign entity will be subject to an export control review and the company will only receive licenses to the technology. US Government will own the IP rights to the technology.

References

1. Department of Commerce: http://www.access.gpo.gov/bis/ear/ear_data.html
2. Department of State:
http://pmddtc.state.gov/regulations_laws/itar_consolidated.html
Follow link to "Part 121 - The United States Munitions List"
3. Space Act Agreement Guidelines:
http://www.nasa.gov/pdf/289016main_Space%20Act%20Agreements%20Guide%202008.pdf

6. Flow of funds

For any work performed at NASA/JPL money needs to be in place before any work can begin. It is envisioned that a company seeking to work with JPL/NASA will, in addition to its own funding, be able to seek funding from Innovation Norway, and the Research Council of Norway. Smaller companies may also be able to tap into technology development funding from the larger Norwegian corporations, for example Statoil's Loop program. ARENA IO is available to provide guidance on potential funding sources.

After all agreements with NASA/JPL and potentially Caltech have been signed, and funding is made available, these funds will have to be transferred to NASA HQ. From there the funds will be transferred to JPL and made available to the researchers assigned to the project. Estimated time for this transfer is about two months. This needs to be taken into consideration when determining the start date for a potential project. See **Figure 7: Flow of Funds**

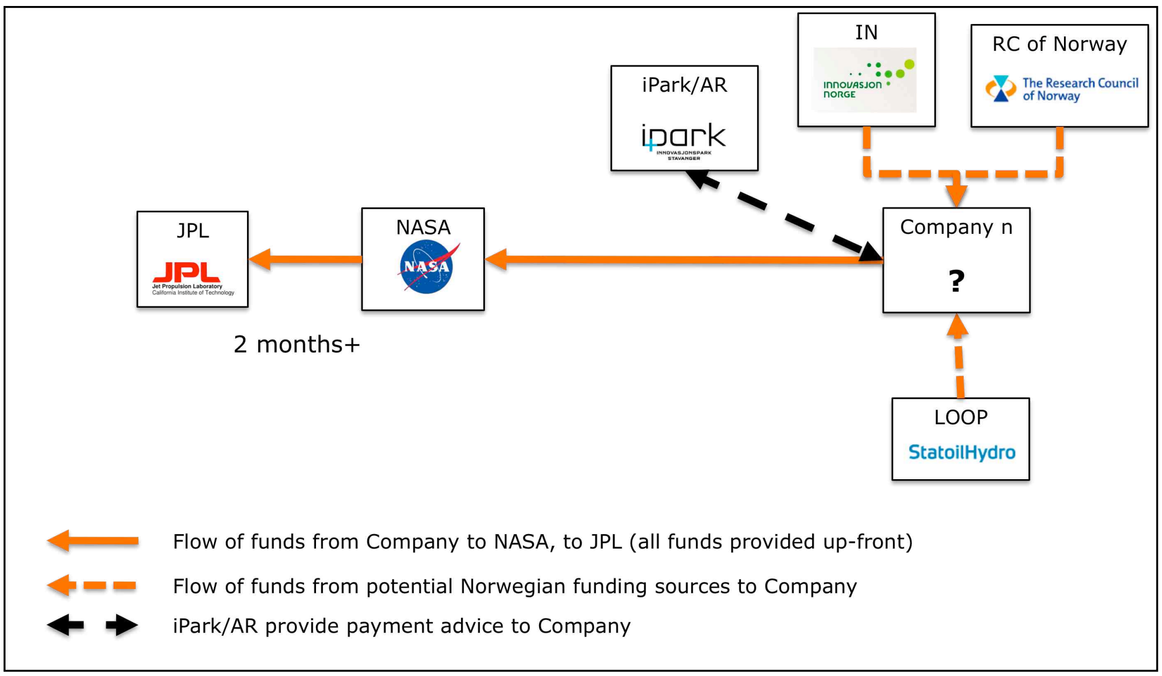

Figure 7: Flow of Funds

Conclusions

Funds for development projects will have to be available for the researchers at JPL/NASA before their work can start. Estimated time from funds are received at NASA HQ to they are available to the JPL researchers is about two months.

7. Initial technology development project with JPL

One of the ambitions of the study was to pick a concrete collaboration project to make this study more than a theoretical exercise, and to use this first project to learn more about the steps any such project would have to go through.

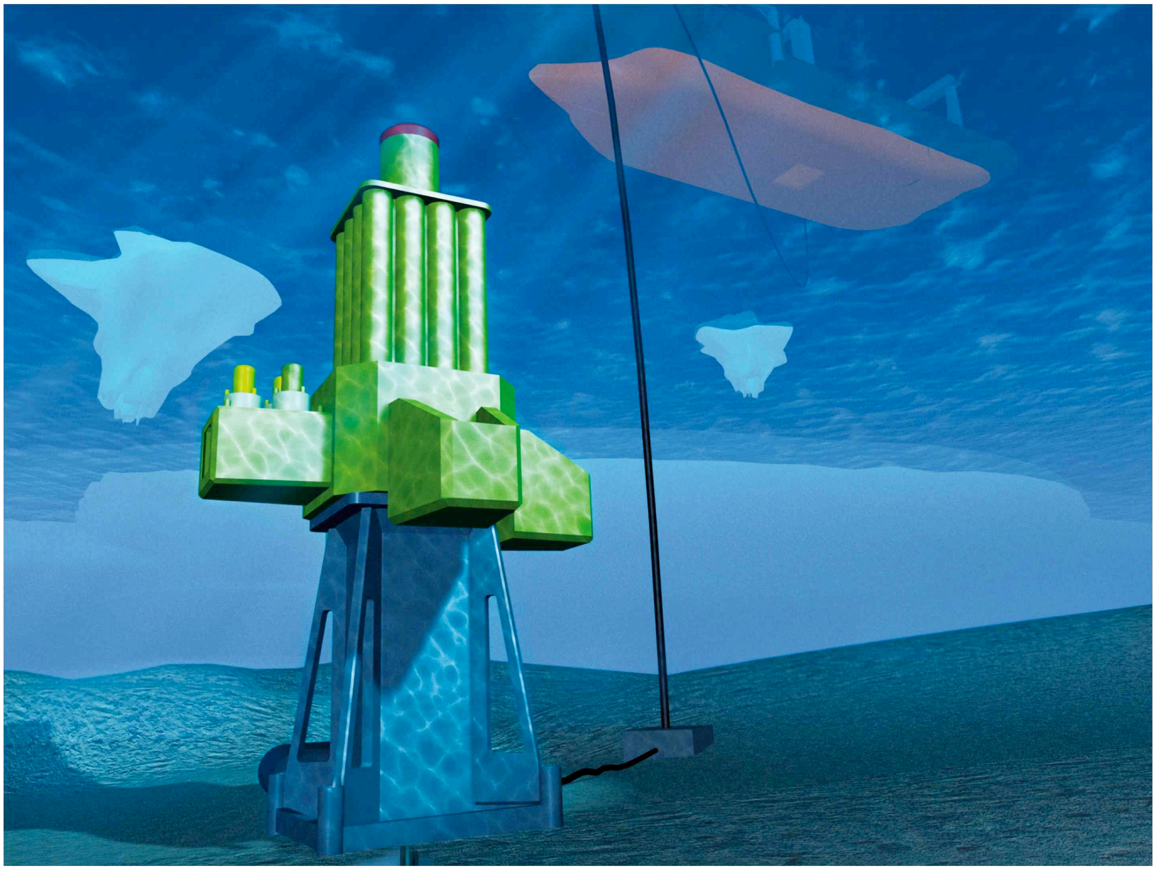

Figure 8: Seabed Rig (Ref. 2)

A number of technology development projects were reviewed. Finally, after careful consideration by the Steering Committee, a Seabed Rig (Ref. 1) project was selected. It was clear that this project represented a good match between the technology NEEDS of Seabed Rig and the capabilities that JPL could OFFER.

In short, Seabed Rig is developing an unmanned drill rig for the offshore oil and gas industry, to sit on the seabed in deep water and potentially under the ice in arctic areas. The rig includes an encapsulated chamber with a pipe handler and a pair of robot manipulators. Statoil has said about Seabed Rig, "this the "Lunar Landing" for the oil and gas industry…."

Meetings were held between Seabed Rig and JPL/NASA at JPL/NASA's location in Pasadena. To address the different aspects of the selected technology development project, two task plans were set up by JPL/NASA. SIMTANO served as discussion partner for Seabed Rig and liaison between Seabed Rig and JPL in this process.

The plan is to have JPL provide support to Seabed Rig in two main areas:

One; in developing a surveillance system for monitoring the activities on drill floor. It would include a system for sensing location and state of objects on the drill floor, and a system for recognizing these objects and provide their position and orientation.

Two; in developing a Drilling Composer for autonomously setting up a sequence of Seabed Rig activities. The Drilling Composer would receive a set of input task goals and automatically translate these goals into a parameterized activity schedule that will be executed by the Drilling Conductor.

These tasks fit well with JPL's unique expertise in fault protection/monitoring for spacecraft and planetary rovers and landers, sensing technologies for extreme environments, and it's expertise in developing automated activity scheduling for spacecraft, including planetary rovers and landers.

Project start was initially scheduled for March 2010. That has now been moved to October/November, 2010. The NASA and ITAR approval processes will determine the final start time.

References

1. Seabed Rig: http://seabedrig.no/
2. Image courtesy Seabed Rig

8. JPL Workshop

The Steering Committee has recommended that a potential workshop be held in either May of June of 2010. The objective of the workshop would be to discuss face-to-face potential areas for collaboration between the Norwegian Energy industry and JPL/NASA with the intention of defining concrete projects for collaboration. Two-collaboration will be sought.

The workshop would be scheduled for two days. It would include presentations by technology experts from the Norwegian and JPL sides. Ample time would be provided for discussions. All participants would provide their presentations and other relevant company and technology background information before the workshop. Tours of the JPL facilities and laboratories would be included in the program.

Number of participants will be limited. The plan would be to send invitations to the members of the Steering Committee, selected researchers at JPL/NASA, representatives from the Royal Norwegian Embassy in D.C. and the Royal Norwegian Consulate in San Francisco, Seabed Rig, and very few selected technology companies in Norway.

A hotel in Pasadena, close to JPL/NASA would be selected for hosting the conference.

An organization committee would be formed to set up to define the program. SIMTANO has offered to serve as secretariat for the workshop.

9. JPL technology grant to a Norwegian postdoctoral researcher

NASA and JPL offer post-doc positions in the areas of planetary; astrophysics and space; climate, oceans, and solid Earth; and Earth atmospheric sciences. Full lists are provided in Ref. 1 and 2. Focus is on science. These positions are competitive. Post doc positions for technology development projects are typically not offered.

On the other hand, JPL and NASA have opened up for technology collaboration projects to bring in and pay for their own external researchers. Researchers through a Caltech project would cost about $110.000,- per year, and through a JPL project about $242.000,- per year. These amounts would cover access to facilities and salary for the researchers while they are at JPL or Caltech. Housing is not included.

This could open up golden opportunities for the best and the brightest technology developers and scientists in Norway to come and work at JPL or Caltech on various collaboration projects. For example, for the Seabed Rig project, one could envision giving one of their robotics experts an opportunity to work on the project at JPL with the JPL robotics experts. In general, as in most other countries, these researchers would only be given access to open-source literature while they are at JPL or Caltech, and will have limited computer access.

Information about how to obtain a visa for these positions is provided at the Embassy of the United States, Oslo website (Ref. 3)

References

1. NASA Postdoc positions: http://www2.orau.gov/NASA_Catalog/
2. JPL postdoc positions:
http://postdocs.jpl.nasa.gov/researchapplicants/jobpostings/
3. Professor and Research Scholar entry requirements:
http://exchanges.state.gov/jexchanges/programs/professor.html

10.Suggested next steps

Through this study valuable insight was gained into the process and steps for setting up collaboration between Norwegian Energy companies and JPL. One of the ambitions of the study was find a way to streamline the process both on the Norwegian and JPL and NASA sides.

On the Norwegian side, ARENA IO has stepped up to support Norwegian companies seeking to work with JPL/NASA. SIMTANO has agreed to do the same in California. The NASA side is still an unknown. Discussions have been held with the Science Attaché at the Royal Norwegian Embassy to investigate how they can support the process at NASA HQ and possibly the Department of State and the Department of Commerce. They have communicated a willingness to help out.

Step 1: There is a need to define how and who to work with NASA HQ, and possibly the Department of State and Department of Commerce. SIMTANO is willing to support this effort.

The Norwegian purchase of the Joint Strike Fighters (JSF) from Lockheed Martin puts reciprocity purchase demands on Lockheed Martin. The issue has already been discussed with the Defense Attaché at the Royal Norwegian Embassy.

Step 2: Investigate whether the JSF reciprocity program could be used as a vehicle for developing technology collaboration programs between Norway and the space related programs that Lockheed Martin is involved with. SIMTANO is wiling to support this effort.

Statoil had discussions with representatives from NASA and JPL in 2004. Based on those discussions concrete suggestions for collaborations were made.

Step 3: Now, after having understood the practical steps for setting up a collaboration effort with JPL and NASA, this may be a good time for contacting these representatives again. Potentially their involvement could smooth out some of the bureaucratic challenges.

Step 4: Investigate how the Norway - U.S. Science and Technology Agreement, signed in 2005, may be used to support specific technology collaboration between the Norwegian Energy sector and NASA and JPL. The Norwegian Ministry of Education and Research should if possible be involved in this effort.

Step 5: Make a concentrated effort to inform relevant Energy related companies in Norway and their potential US subsidiaries about what a technology collaboration with JPL and NASA could mean. Conferences, organizations, press, etc. should be used in this effort. For example, the results of the study will be presented at the annual “Autonomy in Integrated Operations (IO)” conference to be held in Stavanger, February 10-11, 2010.

11.Acknowledgements

At the first Autonomy in Integrated Operations Conference, February 2009, it was decided define and take concrete steps aimed at improving the Norwegian oil and gas industry in the areas of automation and autonomy. Norsk Forening for Automatisering (Norwegian Association for Automation – NFA) organized the conference. This study is the first concrete step.

A number of people and institutions have contributed to the findings and conclusions presented in this report. The Steering Committee members including the author are deeply grateful to them all.

The author will especially like to recognize Trond Lilleng of Statoil, Martin Sigmundstad of ARENA IO, Lars Annfinn Ekornsœter of NFA, and Issa Nesnas of JPL for their support in defining this study; Endre Tjetland Nesse of SIMTANO for setting up, conducting and, providing a summary findings from the survey discussed in Section 1; Innovation Norway, Statoil, Kongsberg Maritime, FMC Technologies, JPL, NFA, SIMTANO AS, ARENA IO for providing funding (cash or in-kind); and Martin Sigmundstad of ARENA IO, Sigurd Moe of FMC Technologies, Issa Nesnas and Khaled Ali of JPL, Bjørn Jalving of Kongsberg Maritime, Lars Annfinn Ekornsœter of NFA, Geir Hovmork of the Norwegian Space Center, and Brage Wårheim Johansen and Cato Wille and John Egil Johannessen of Statoil for being valuable members of the Steering Committee.

The Steering Committee will further like to recognize Luther Beegle and Tara Estlin at JPL for setting up task plans for a Seabed Rig effort; Roald Valen at SeaBed Rig for providing input and feedback during the development of the task plans; Linda Rodgers at JPL for providing insight into researcher opportunities at JPL, NASA, and Caltech; Robert Chan at JPL for providing valuable JPL and NASA contract information; David Tralli at JPL for valuable and practical insight into how to organize domestic and foreign collaborations; Mark Homer at NASA, Gary Kramer at NASA, Kien Le at Caltech, and Nancy Barker at JPL for providing insight into foreign partner related legal issues; and Karina Edmonds at Caltech for providing licensing and royalty insights; Berit Johne at the Royal Norwegian Embassy for her suggestions on how the Embassy could support a collaboration effort; Svein-Egil Nielsen for feedback and general suggestions on potential use of the Joint Strike Fighter (JSF) reciprocity purchase agreements; and finally Tom Ivar Stie at the Royal Norwegian Embassy for his detailed insights into potential use of the JSF reciprocity purchase agreements for technology collaborations such as this.

12. ORGANIZATION

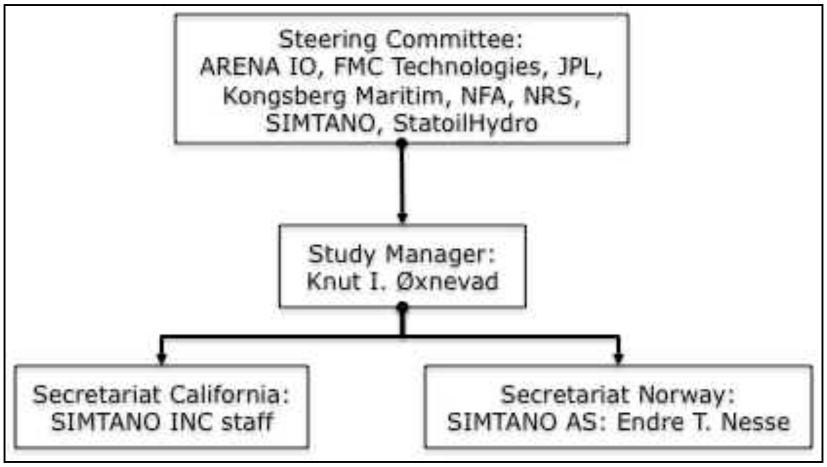

Figure 9: Organizational Structure

The study was organized as shown in **Figure 9: Organizational Structure**. The Steering Committee reviewed study findings and gave directions to the study.

Steering Committee Members listed alphabetically according to organization: ARENA IO (Martin Sigmundstad), FMC (Sigurd Moe), Jet Propulsion Laboratory – JPL (Issa Nesnas, Khaled Ali), Kongsberg Maritime (Bjørn Jalving), Norsk Forening for Automatisering – NFA (Lars Annfinn Ekornsœter), Norwegian Space Centre (Geir Hovmork), SIMTANO (Knut I. Øxnevad), Statoil (Brage Wårheim Johansen, Cato Wille).

Six Steering Committee Meetings were held: June 16, June 26, August 4, August 18 and September 25, and November 5, 2009. The were all held over the net, using a combination of telephone and GoToMeeting.

APPENDIX A

The Jet Propulsion Laboratory - JPL

Jet Propulsion Laboratory (http://www.jpl.nasa.gov), part of Caltech (Appendix B), has developed nearly all of National Astronautics and Space Administration's (NASA: Appendix C) outer planet missions. Among them the Viking missions to Mars, Cassini, and now lately the Mars rovers, Spirit and Opportunity. JPL is regarded as one of the finest centers in the NASA system. It employs some 5200 engineers and scientist. A large percentage of these have doctorate degrees.

Here is what the director of JPL, Dr. Charles Elachi says about the activities of the laboratory (http://www.jpl.nasa.gov/about/index.cfm). He himself is a highly respected scientist.

"Do not go where the path may lead," wrote Ralph Waldo Emerson. "Go instead where there is no path, and leave a trail." That could be the motto of the Jet Propulsion Laboratory. Trailblazing has been the business of JPL since it was established by the California Institute of Technology in the 1930s. America's first satellite, Explorer 1 which launched in 1958, was created at JPL. In the decades that followed, we sent the first robotic craft to the moon and out across the solar system, reconnoitering all of the planets. Pushing the outer edge of exploration, in fact, is the reason JPL exists as a NASA laboratory.

In that spirit, this is an exceptionally busy period for JPL in laying new paths. An exciting step in the search for exoplanets took place recently when we launched Kepler, a spaceborne telescope that will seek out Earth-like planets as they pass in front of other stars. JPL is contributing key technology to two European Space Agency spacecraft to be launched together in April, Herschel and Planck. Later this year we will launch another observatory, the Wide-field Infrared Survey Explorer. They join our currently operational Spitzer Space Telescope and Galaxy Evolution Explorer astronomical missions. Among our robotic spacecraft arrayed across the solar system, Dawn is using ion propulsion to take it into orbit around two bodies for the first time ever -- the large asteroid Vesta and the dwarf planet Ceres. Mars Reconnaissance Orbiter is returning exceptionally detailed photos of the Red Planet's surface, while the rovers Spirit and Opportunity keep going far beyond the mission they were originally designed for. Last year the Phoenix lander successfully found water ice on Mars' arctic plains. The flagship explorer Cassini continues its orbits of Saturn, scrutinizing the ringed planet and its moons, including the haze-shrouded Titan in an extended mission. The Voyagers are exploring the edge of our solar system.

Closer to home, a contingent of Earth-orbiting satellites monitors the lands, oceans and atmosphere of our own planet, returning important information on topics ranging from atmospheric ozone to El Nino events. These include the Jason 2 satellite launched last year on a joint U.S./French mission to monitor Earth's oceans.

In total, JPL has 18 spacecraft and eight instruments conducting active missions. All of these are part of NASA's program of exploration of Earth and space with plans to send robots and humans to explore the moon, Mars and beyond.

These ventures would not be possible without NASA's Deep Space Network managed by JPL. This international network of antenna complexes on several continents serves as the communication gateway between distant spacecraft and the Earth-based teams that guide them. While carrying out these exploration missions, JPL also conducts a number of space technology demonstrations in support of national security and develops technologies for uses on Earth in fields from public safety to medicine, capitalizing on NASA's investment in space technology. The stories of these mighty things we dare are told in the pages that begin here.

Dr. Charles Elachi Director

APPENDIX B

California Institute of Technology - Caltech

Caltech (http://www.caltech.edu/) is ranked as one of the best Engineering and Science Universities in the United States. Here are some essential facts about this fine institution (http://www.caltech.edu/at-a-glance/)

Mission Statement

The mission of the California Institute of Technology is to expand human knowledge and benefit society through research integrated with education. We investigate the most challenging, fundamental problems in science and technology in a singularly collegial, interdisciplinary atmosphere, while educating outstanding students to become creative members of society.

Academic Divisions

Biology
Chemistry & Chemical Engineering
Engineering & Applied Science
Geological & Planetary Sciences
Humanities & Social Sciences
Physics, Mathematics & Astronomy
Interdisciplinary Programs

Faculty & Staff Statistics

Faculty in residence (as of December 2008)
Professorial faculty 294
Emeriti 108
Research faculty 57
Other faculty 65
Visiting faculty 138
Postdoctoral scholars 535
Senior postdoctoral scholars 36
Visitors 115

Employees as of December 2008
Campus (excludes faculty and students) 2,650
JPL (excluding contractors) 5,200

Honors & Awards (as of December 2008)
Caltech faculty and alumni have received wide recognition for their achievements in science and engineering.
Nobel Prize: 31 recipients, 32 prizes
Crafoord Prize: 5 recipients
National Medal of Science: 49 recipients
National Medal of Technology: 10 recipients
California Scientist of the Year: 15 recipients
Fellow, American Academy of Arts and Sciences: 85 faculty
Member, National Academy of Sciences: 75 faculty

Member, National Academy of Sciences, Institute of Medicine: 4 faculty
Member, National Academy of Engineering: 30 faculty
A full list of Caltech Nobel and Crafoord laureates can be fo**und at http://www.caltech.edu/nobel-c**rafoord
Brief bios of Nobel Laureates are availa**ble at http://pr.caltech.edu/events/caltech**_nobel/.

APPENDIX C

National Astronautics and Space Administration's - NASA

NASA (http://www.nasa.gov) has a number of centers throughout the US. The more important ones are Ames Research Center, JPL, Goddard Space Flight Center, John H. Glenn Research Center, Langley Research Center, George C. Marshall Space Flight Center, John F. Kennedy Space Center, Lyndon B. Johnson Space Center. NASA's budget for fiscal year 2010 is expected to be in the USD18.7 bill. This makes the NASA budget some 4 times larger than the budget of the European Space Agency (http://www.esa.int/esaCP/index.html). In NASA's words, here is what this fine organization does (http://www.nasa.gov/about/highlights/what_does_nasa_do.html):

NASA's mission is to pioneer the future in space exploration, scientific discovery and aeronautics research.

To do that, thousands of people have been working around the world -- and off of it -- for 50 years, trying to answer some basic questions. What's out there in space? How do we get there? What will we find? What can we learn there, or learn just by trying to get there, that will make life better here on Earth?

A Little History

President Dwight D. Eisenhower established the National Aeronautics and Space Administration in 1958, partially in response to the Soviet Union's launch of the first artificial satellite the previous year. NASA grew out of the National Advisory Committee on Aeronautics (NACA), which had been researching flight technology for more than 40 years.

President John F. Kennedy focused NASA and the nation on sending astronauts to the moon by the end of the 1960s. Through the Mercury and Gemini projects, NASA developed the technology and skills it needed for the journey. On July 20, 1969, Neil Armstrong and Buzz Aldrin became the first of 12 men to walk on the moon, meeting Kennedy's challenge.

Meanwhile, NASA was continuing the aeronautics research pioneered by NACA. It also conducted purely scientific research and worked on developing applications for space technology, combining both pursuits in developing the first weather and communications satellites.

After Apollo, NASA focused on creating a reusable ship to provide regular access to space: the space shuttle. First launched in 1981, the space shuttle has had 120 successful flights. In 2000, the United States and Russia established permanent human presence in space aboard the International Space Station, a multinational project representing the work of 16 nations.

NASA also has continued its scientific research. In 1997, Mars Pathfinder became the first in a fleet of spacecraft that will explore Mars in the next decade, as we try to determine if life ever existed there. The Terra and Aqua satellites are flagships of a different fleet, this one in Earth orbit, designed to help us understand how our home world is changing. NASA's aeronautics teams are focused on improved aircraft travel that is safer and cleaner.

Throughout its history, NASA has conducted or funded research that has led to numerous improvements to life here on Earth.

Organization

NASA Headquarters, in Washington, provides overall guidance and direction to the agency, under the leadership of the Administrator. Ten field centers and a variety of installations conduct the day-to-day work, in laboratories, on airfields, in wind tunnels and in control rooms.

NASA Today

NASA conducts its work in four principle organizations, called mission directorates:

Aeronautics: pioneers and proves new flight technologies that improve our ability to explore and which have practical applications on Earth.

Exploration Systems: creates new capabilities and spacecraft for affordable, sustainable human and robotic exploration.

Science: explores the Earth, moon, Mars and beyond; charts the best route of discovery; and reaps the benefits of Earth and space exploration for society.

Space Operations: provides critical enabling technologies for much of the rest of NASA through the space shuttle, the International Space Station and flight support.

In the early 21st century, NASA's reach spans the universe. Spirit and Opportunity, the Mars Exploration Rovers, are still studying Mars after more than three years. Cassini is in orbit around Saturn. The Hubble Space Telescope continues to explore the deepest reaches of the cosmos.

Closer to home, the latest crew of the International Space Station is extending the permanent human presence in space. Earth Science satellites are sending back unprecedented data on Earth's oceans, climate and other features. NASA's aeronautics team is working with other government organizations, universities, and industry to fundamentally improve the air transportation experience and retain our nation's leadership in global aviation.

The Future

In the next 20 years, NASA will be laying the groundwork for sending humans not only beyond Earth's orbit, but further into space than they've ever been. The next key steps are:

Complete the International Space Station and retire the Space Shuttle by 2010

Begin robotic missions to the moon by 2008 and return people there by 2020

Continue robotic exploration of Mars and the Solar System

Develop a crew exploration vehicle and other technologies required to send people beyond low Earth orbit

Though nearly 50 years old, NASA is only beginning the most exciting part of its existence.