SUBJECT: JIP Drilling Systems Automation Roadmap Funding Support Request
Date: July 10 2016

Executive Summary

A comprehensive Drilling Systems Automation Roadmap (DSA-R) that describes the next 10 years of potential development is a highly valuable document for the upstream oil industry. There is a significant desire to realize value for drilling systems automation. Specific applications have been successful for both operators and suppliers. However, the development of an overall integrated application between various companies appears too complex to achieve in the near term. A roadmap will describe the path these companies can take to develop an early integrated solution.

The DSA–R program was launched as an all-volunteer cross industry initiative. It includes various oil field experts from key companies as well as automation experts from outside oil and gas who bring advanced insights to the program.

This program has followed a structured process from Sandia National Laboratories and developed many insights that have been partially published, a few have been spun off to the Drilling Systems Automation Technical section of SPE for further near term development and some have provided insights for the IADC Advanced Rig Technology Committee (ART).

This all volunteer initiative has progressed at a much slower pace than the typical funded industry roadmap initiatives. This slow rate of progress will continue unless funding is obtained to enable resource to be devoted to compiling the knowledge that has been and continues to be developed.

This proposal is to request funding from 10 companies for the DSA-R program manager to be able to commit the time to develop the Stage 1 report in 6 months which will bring the first version of a comprehensive overview of a drilling systems automation roadmap. Without funding, this deliverable will take around 2 years or more. In the current low oil price environment, this difference in delivery time can create huge value for the industry.

The proposal is for 10 companies to sponsor $10,000 each to fund this JIP.

Proposal

This proposal requests financial support from the industry in the form of a JIP to enable the completion of Stage I report on the Drilling Systems Automation Roadmap (DSA-R) initiative for the benefit of the upstream oil and gas industry.

The Drilling Systems Automation Roadmap Industry Initiative has run as a wholly volunteer effort for almost 3 years. The pace of development has been driven by the availability of the volunteers' time and the drive / availability of the program manager. Most industry roadmaps (Department Of Defense – Unmanned Systems Integrated Roadmap; Department of Energy Technology - Roadmap to Secure Control Systems in the Energy Sector, International Energy Agency – Energy Technology Roadmaps; Roadmap for the US Petroleum Industry, Petroleum Industry of the Future, , …) are developed in a shorter time frame because they are heavily funded with resources dedicated to the work. A body of work has been generated that requires effort to compile into the first full report as well as some work requires a dedicated resource to complete the content sufficient for the report.

The financial support from a JIP will be used to retain the services of the DSA-R program manager to undertake much of the work required to complete this critical stage I report. The program manager, John de Wardt, is a highly experienced and well published industry consultant who, through the role of DSA-R program manager, has the most oversight of the work produced and the work needed to complete this Stage I report.

The support request is for $95,000 over a six month period.
The intent is to have 10 companies fund this for $10,000 each. The extra $5,000 is contingency.

The all-volunteer committee has already donated an effective $300,000 over the first 3 years of this program and the program manager, John de Wardt – DE WARDT AND COMPANY, is committing an extra $80,000 for this Stage I report in the form of a fee discount.

Background

Technology roadmapping is an important tool for collaborative technology planning and coordination for entire industries. As a result of technology roadmapping, an industry can make better investment decisions because it has better information to:

- Identify critical product needs that will drive technology selection and development decisions.
- Determine the technology alternatives that can satisfy critical product needs.
- Select the appropriate technology alternatives.
- Generate and implement a plan to develop and deploy appropriate technology alternatives.

At the industry levels, technology roadmapping has several potential uses and resulting benefits. Three major uses are:

- First, technology roadmapping can help develop a consensus about a set of needs and the technologies required to satisfy those needs.
- Second, it provides a mechanism to help experts forecast technology developments in targeted areas.
- Third, it can provide a framework to help plan and coordinate technology developments both within a company or an entire industry.

The main benefit of technology roadmapping is that it provides information to help make better technology investment decisions. It does this by:

- First, identifying critical technologies or technology gaps that must be filled to meet product performance targets.
- Second, identifying ways to leverage R&D investments through coordinating research activities either within a single company or among alliance members.

The oil and gas drilling industry has identified drilling systems automation as a key potential value driver of drilling performance (thence well construction costs). There is a desire to advance the application of drilling systems automation however there are a number of barriers that require overcoming to succeed earlier rather than later. An industry technology roadmap offers the means to provide insight to overcome these barriers and deliver the technology earlier than it could otherwise be delivered. Earlier delivery is very desirable in the current low oil price environment because effectively implemented drilling systems automation is expected to reduce well costs.

The DSA-R cross industry initiative was launched in June 2013 by 3 co-founders to address the industry need for a common understanding of how drilling systems automation is anticipated to develop thus providing a foundation to support accelerated implementation. This initiative is affiliated with IADC (Advanced Rig Technology Committee), SPE (Drilling Systems Automation Technical Section) and AUVSI (Association of Unmanned Vehicles International. Contacts have been made with ISA (International Association of Automation) and Institute of Electrical and Electronic Engineers to expand this affiliation across a broader industry network.

The Process

The founders of the DSA-R undertook a review of roadmaps and roadmapping processes in domains considered to be similar to Drilling Systems Automation (DSA). The roadmapping process developed and published by Sandia National laboratories, for unlimited release, was found to be the most appropriate example for adoption for the DSA Roadmapping process. In fact, it forms the basis of the version in Wikipedia and is the similar format to that adopted by IEA in their guide to energy technology roadmaps.

The DSA-R process description document was developed from the Fundamentals of Technology Roadmapping report issued by the Strategic Business Development Department, Sandia National Laboratories. Authors: Marie L. Garcia & Olin H. Bray; SAND97-0665 - Unlimited Release by John de Wardt and reviewed by Ed Tovar & Daniel Declute-Melacon (the three founders).

The steering committee was formed by the founders; this met repeatedly to develop the foundation and then the challenges. The meetings were all held via video conference coordinated by the program manager using GoToMeeting. As a result of a company re-assignment, Daniel Declute-Melacon dropped out of the program. John de Wardt took the role of program manager as he had been leading the process and Ed Tovar the role of deputy program manager.

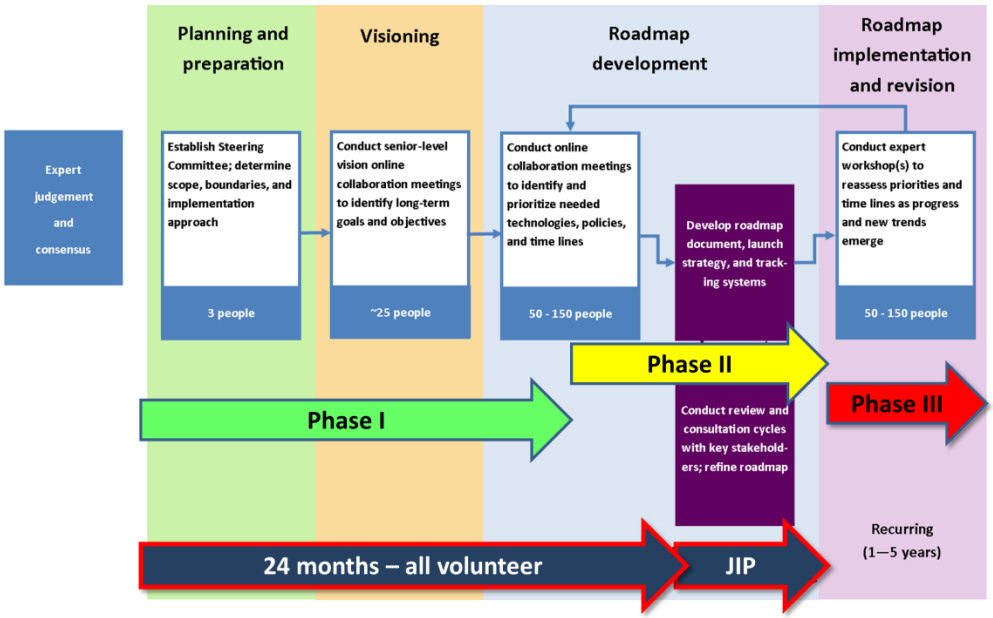


Figure 1 – DSA – Roadmap Phases based on Sandia national Labs Roadmap Process

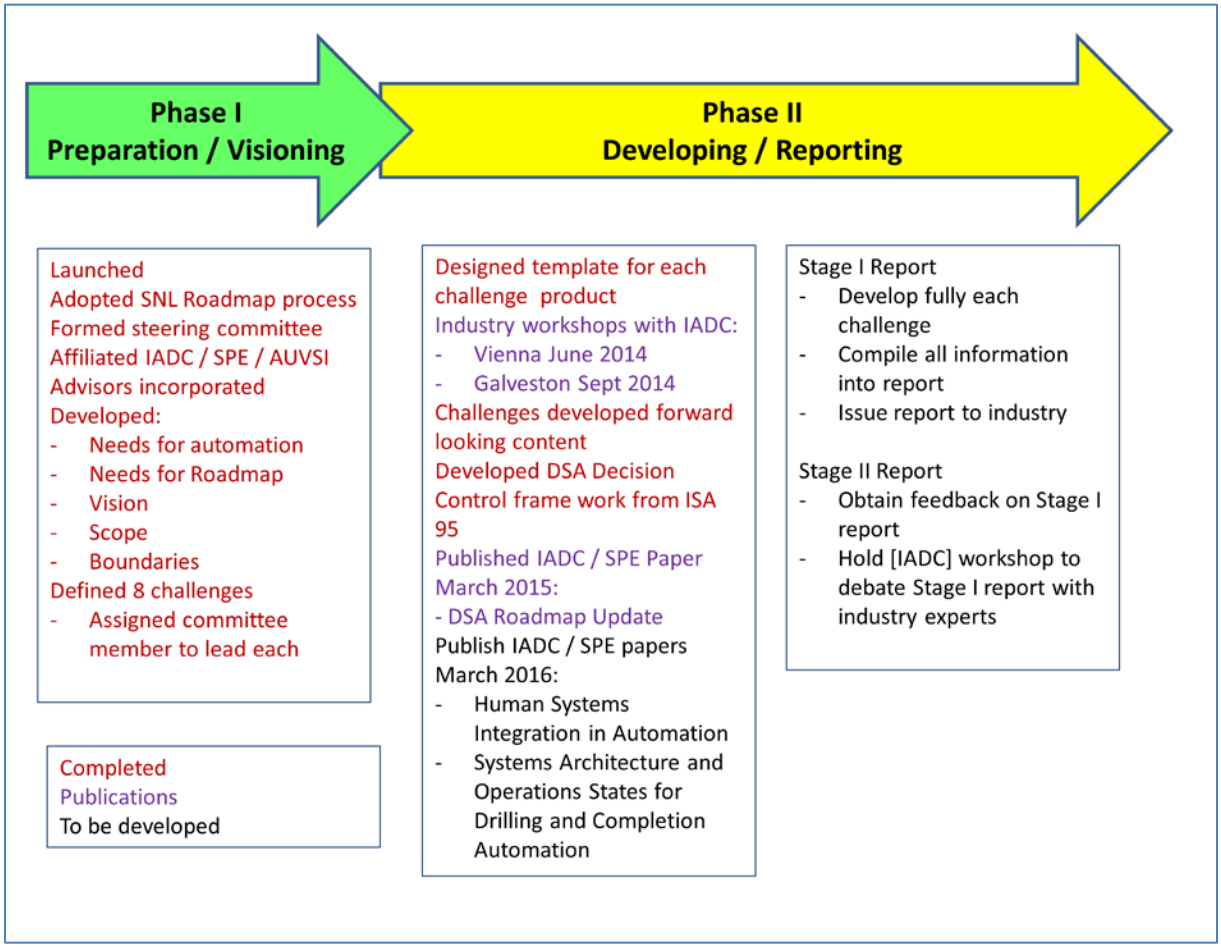


Figure 2 – DSA – Roadmap Phases based on Sandia national Labs Roadmap Process

Phase I: Foundation Phase

Summary of Phase I of the DSA-R Industry Initiative.

- Launched this all volunteer initiative June 2013.
- Identified the Sandia National Labs Technology Roadmap process as the best to adopt and adapted it to our purpose.
- Formed a committee of industry experts covering the necessary range of skill sets (listed below).
- Affiliated to IADC ART, SPE DSATS and AUVSI (Association of Unmanned Vehicle Systems International).
- Operate in the virtual world using video conferences, web, e-mail.
- Brought on board three key, experienced advisors (listed below).
- Developed the needs, visions and boundaries

- Defined 8 key challenges that require mapping to effectively describe the future potential implementation of DSA-R. Listed below. A 9th key challenged was added early 2016.
- Assigned a committee member to lead each key challenge; built sub teams to work on each with more industry experts – currently around 50 people involved.

The Committee

Program Manager / Founder: John de Wardt, DE WARDT AND CO
Deputy Program Manager / Founder: Ed Tovar, InTechSy
Steering committee:

- Mark Andersen (Shell)
- Eric Cayeux (IRIS)
- Amanda DiFiore (Circadian)
- Blaine Dow (MI Swaco)
- Clay Flannigan (SWRI)
- Slim Hbaieb (Schlumberger)
- Calvin Inabinett (Aerodyne Industries)
- Moray Laing (SAS / SPE DSATS)
- Terry Loftis (Transocean / IADC ART),
- Robin Macmillan (NOV / IADC ART / SPE DSATS)
- John Macpherson (Baker Hughes / SPE DSATS)
- Bob Moran (Halliburton)
- Randy Mutch (Ensign)
- Lindsay Voss (AUVSI)
- Mario Zamora (Retired - MI Swaco)

Advisors

Significant standing and history in automation systems transformations:

- John Berra — Past Chairman Emerson Process Management. He was a critical industry leader during the industrial automation process in the 1990's and a key proponent of open systems architecture during the "Fieldbus Wars".
- Eric Nettleton — formerly Rio Tinto. He was the key technology manager developing the autonomous mine application in Western Australia.
- Tom Sheridan – Professor Emeritus MIT, creator of the 10 levels of automation and expert on Human Systems Integration.

Affiliates

Multiple institutions joined this endeavor though affiliation creating a broad footprint of connectivity while remaining institution agnostic enabling participation with all:

- IADC [ART]
- SPE [DSATS]
- AUVSI
- ISA (in discussion)
- IEEE (invited)

Needs for Drilling Systems Automation Roadmap

The oil and gas industry is fragmented in structure creating a difficult environment in which to adopt industrial automation. There is a degree of fear over the application of automation including a lack of understanding of what it is, a lack of definition on how it will function, minimal rewards for implementation and the threat to employment of individuals leading to lost revenues.
Furthermore, the managers who control the investment in new DSA technology and business processes have no clear description of what it is and how it can deliver value to them.
This roadmap will support a consensus on a set of needs leading to the developments required to satisfy those needs; it will provide a mechanism to help forecast how these developments will progress and provide a framework to coordinate between disparate players. It will enable non-oil and gas industry players with applicable expertise to envision how they can contribute to the implementation of drilling systems automation.

The Foundation and Eight Key Challenges

Systems architecture was identified as a foundation of successful automation application. In order to compress the timeline, the exploration of systems architecture for drilling systems automation was scheduled to be undertaken in parallel to the seven challenges identified as the key tracks for the roadmap. These eight challenges are being addressed by separate teams who report to the Program Manager and share their updates with the Steering Committee.

Systems Architecture defines integration and physical interoperability of the drilling system, including prime sub-systems, and includes the hierarchy of workflows, interfaces, definition of states, and other aspects that enable system functionality.

1. *Communications* addresses links among the downhole, surface, remote operating centers, and distributed experts, in addition to standards for common protocols and interoperability, deterministic systems for hardware control, and secure data transport at all levels.
2. *Instrumentation and Measurement Systems* defines the requirements for delivering comprehensive, reliable, quality measurements of the downhole, and surface operations in a timely manner for DSA.
3. *Drilling Machines and Equipment* includes a wide range of surface and downhole drilling equipment and robotics that are highly mechanized and semi-autonomous.
4. *Control Systems* focusses on downhole, surface, and remote systems directed at creating the wellbore and delivering various levels of automation from monitoring through advisory control to autonomous systems.
5. *Simulation Systems and Modeling* covers planning, real-time, offline, remote and post-well modeling, and simulation tools and systems.
6. *Human Systems Integration* addresses the interaction of automation systems with humans and mode issues including human displays, human machine interfaces, role competencies, training, and distributed and decentralized control.
7. *Industry Standards and Certification* identifies available and required standards and regulations that define the operations of automation as well as current and future impacts that can define the ultimate future of DSA.
8. *Contingency Management System*: critical for safe, deterministic, trustable, deployable autonomy – system ability to “get out of trouble” (added Dec 2015)

Total Volunteer Team

The team is now around 50 volunteers organized under the 8 Challenges. Each challenge team leader is responsible for their own team which is also vetted by the Program Manager to ensure active volunteers with credible expertise for the team. Each participant is only permitted to be on one team to ensure they do not dilute their efforts. The challenges progress sporadically and at various paces whereas we desire continuous forward progression in parallel to enable the interdependencies to be mapped, debated and developed. The challenges require coaching to pull forward the laggards and develop the interdependencies to create a coherent and time corresponding result.

Phase II: Development Phase

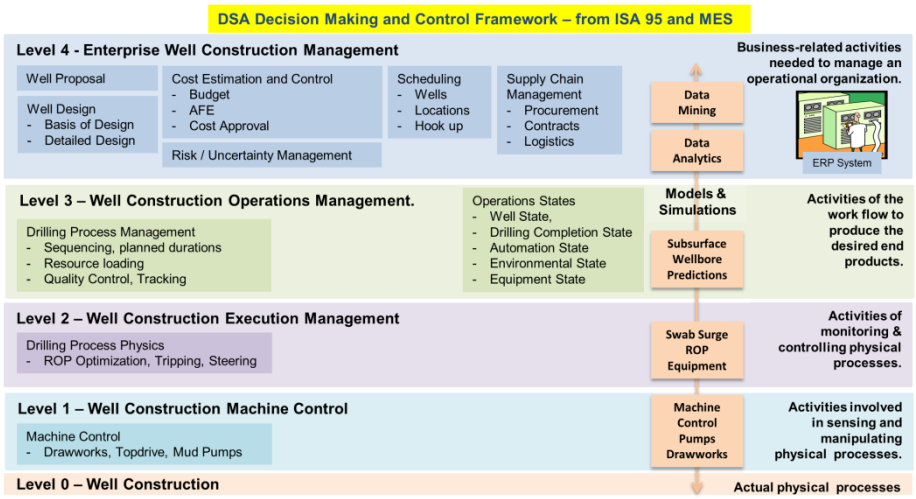
The challenge teams worked under the guidance of the program manager and the steering committee to develop their outlooks. Progressively, each challenge team reported back to the steering committee with each progressing at various rates of progress.

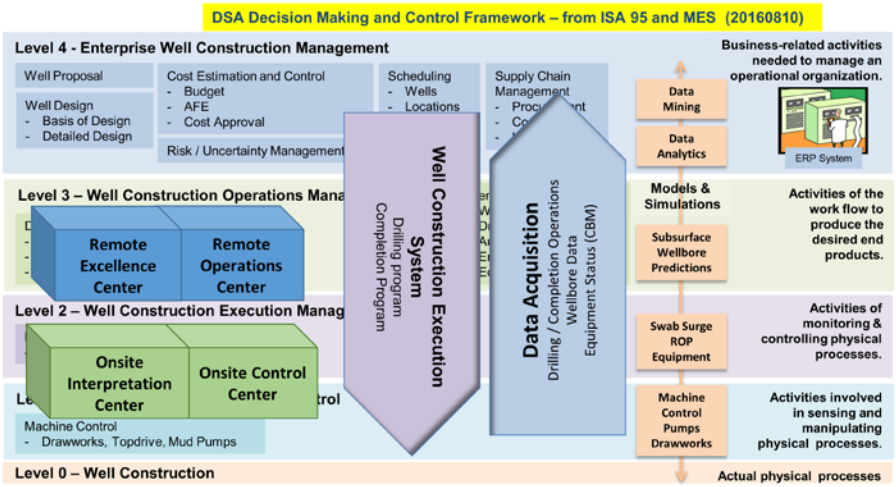
This phase commenced interaction and publication to the industry.

- Held workshops through IADC at IADC World Drilling (69 attendees) in Vienna and IADC ART Conference Galveston (133 attendees) in 2014. Both very well received.
- Published IADC / SPE Paper at 2015 Drilling Conference in London titled: Drilling Systems Automation Roadmap - The Means to Accelerate Adoption. This was the #1 ranked abstract of 504 abstracts submitted for this conference.
- Published SPE / IADC Paper at 2016 Drilling Conference in Ft Worth titled: Human Systems Integration: Key Enabler for Improved Driller Performance and Successful Automation Application. This was the #2 ranked abstract of 383 abstracts submitted for this conference.
- Published SPE / IADC Paper at 2016 Drilling Conference in Ft Worth titled: Systems Architecture and Operations States for Drilling and Completion: The Foundation to Real Performance Measurement and Drilling Systems Automation. This was the #4 ranked abstract of 383 abstracts submitted for this conference.

The very high ranking of the DSA-R abstracts in the IADC / SPE Drilling Conferences ranking is a demonstration of very strong industry interest in this work and quality deliverables by the DSA-R committee.

The 2015 publication included a first of its kind adaption of the ISA-95 hierarchical abstract model of the enterprise for drilling, including control functions and business functions, and its information exchange combined with the manufacturing execution system adaption of ISA-95, creating DSA - Drilling Systems Automation Decision Making and Control Framework.





Phase II requires more work to detail out the story line for each of the key challenges, identify key target applications (deep offshore versus shale drilling on land) and describe key technology / methodology alternatives and timelines.

Typically, industry roadmaps are fully funded endeavors due to the significant workload involved. Examples include DOD funding of Unmanned Systems Integrated Roadmap.
This initiative has consumed huge amounts of volunteer time especially for the Program Manager – John de Wardt; who is actively leading this effort.
We are exploring opportunities to seek funding for Phase II so that the high level of workload can continue and the pace be maintained. Without funding, the whole program will continue only at a slow pace.

This phase compiles the roadmap report and is the first whole publication to present to the industry.

Stage I Report
This will be the first fully developed report from all the challenges. It will be the input to the full review and consultation cycle with the industry intended to occur in Stage II.

Stage II Report
This report will be an update of Stage I report and consider all the feedback solicited via multiple means from the industry – uploaded comments, video conferences and an in person workshop. This critical workshop could be scheduled for end 2016 in Houston and we would ask IADC to organize it on behalf of the DSA-R initiative.

Phase III: Implementation and Revision

This phase has not been defined currently.

Tasks of the DSA-R Initiative

Leadership
This has been provided by John de Wardt initially as a founder then transitioning to the Program Manager on a full volunteer basis. Ed Tovar was also a co-founder and has assumed the role of deputy Program Manager – Ed brings a long experience working with and acting as a Project Manager at DARPA (Defense Advanced Research Projects Agency). John has also had a web site developed to enable the progress to be published to the community and the challenge teams to communicate within themselves and between each other.

Deliverables of the DSA-R Initiative
The DSA-R initiative intends to develop a report that details the expected progression of drilling systems automation over the next 10 years – to 2025. This window in time is expected to be a critical growth and adoption period for this sophisticated technology. The fragmented nature of the drilling and completions business is inhibiting advancement and the roadmap will address ways to overcome this and achieve faster / greater efficiency / lower cost wells earlier than natural progression.

IADC ART has developed best practices and guidelines for automated systems.

SPE DSATS is building foundations on which the industry can cooperate.

DSA-R continues to explore the longer term and provide the roadmap that enables current investment in this complex and potentially highly rewarding technology.

Value Proposition of the DSA-R

The needs for an industry roadmap are compelling. The well drilling and completion industry is highly fragmented, it will require structure to enable the interoperability required to deliver functioning automated / autonomous systems. This will provide definition of supplier opportunities so they can develop applicable products and services. A transformation of this scale across our industry requires consensus on how DSA will develop in order to attract the needed levels of investment. Entry of non-oil and gas industry players will enable the industry to access alternative skills and advanced technologies necessary for accelerating successful adoption. Fear of change to technologies and personnel is high and can be overcome through a clearly communicated comprehensive way forward.

Communicating the business value that DSA can deliver is a key hurdle to implementation. Currently, results have shown improvements in terms of rate of penetration (40% over human driller rotary drilling), building and steering wells (80% improvement while sliding) however the overall value proposition is foreseen by proponents and questioned by traditionalists. A recent offset industry example has demonstrated that when port container handling lift equipment was automated, with supervisory remote control, the whole wharf system became automated. The effect was to increase productivity by 18%, reduce maintenance by 27% and reduce fuel consumption / emissions by 22%. Similar knock on value can occur in applying DSA to the benefit of operators, drilling contractors and service companies.

Pricing for Phase II, Stage I Report

Pricing has been developed to:

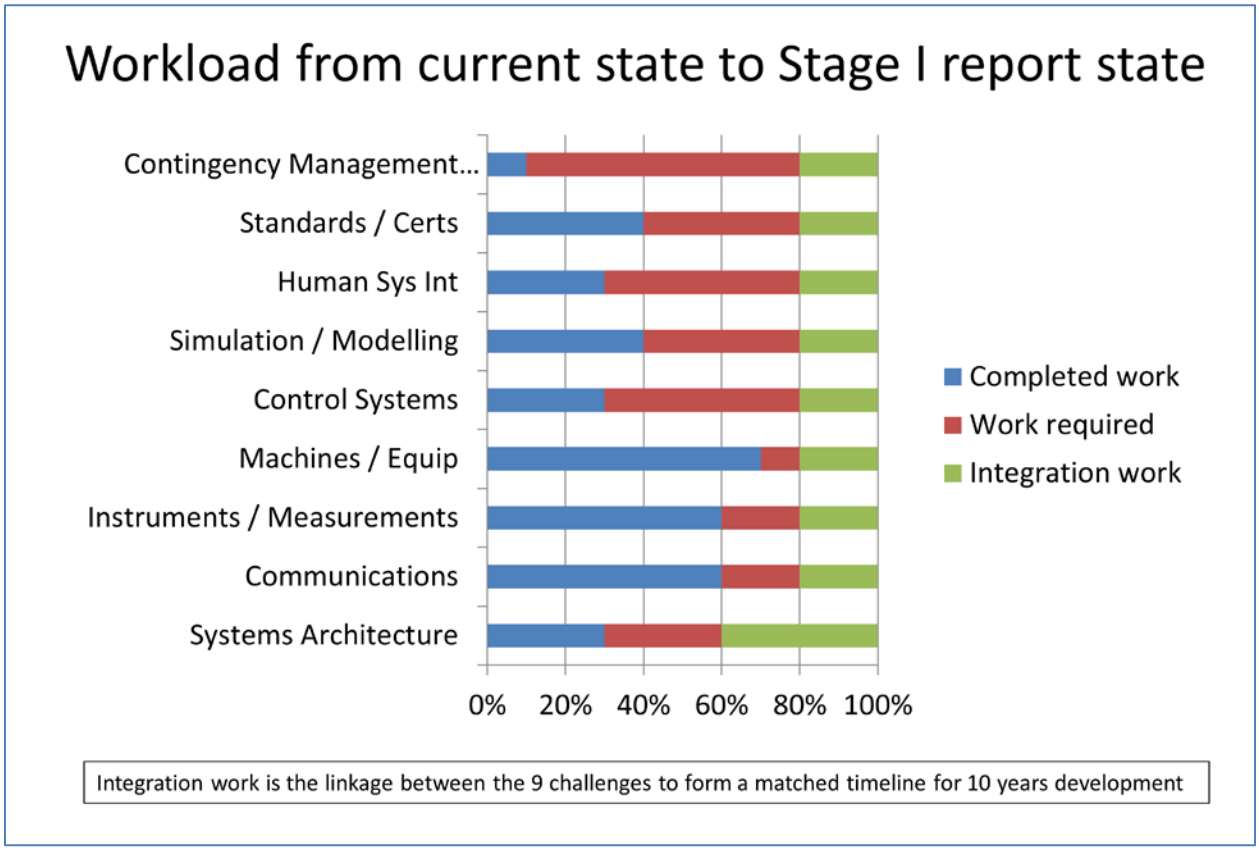
- Draft Stage I report from team products and new writings where gaps exist, review with experts and issue for JIP Funders' review
- Integrate challenge team time lines and highlight interdependencies
- Facilitate JIP Funders workshop for debate, feedback and updating.

The quoted pricing has been developed based on:

- Industry consultant John de Wardt – DE WARDT AND COMPANY (special discounted rate for non-commercial work) - $80,000
- Ad hoc specialist consultant support (such as Tom Sheridan) for some expert input - $10,000
- Expenses – primarily trip(s) to Houston to present the output - $5,000
- Contingency - $5,000

Total cost for Phase II, Stage I report due circa six months after final funding paid - $100,000

The workload required to complete the Stage I report is shown graphically below. Some challenges require significant effort to perform work / develop their future outlook collaborating with experts and, thereafter, the integration process will be undertaken to balance the technologies / timelines in the challenges.



Structure of the Report

The report will be structured according to best practices in major industry roadmaps and the Sandia National Laboratories process.

1. Executive Summary
2. Purpose, Scope and boundaries
3. Needs for automation / needs for a roadmap
4. Vision, Define the product
   4.1. Land multiple wells & offshore exploration
5. Current State /Future State
6. Describe development in terms of systems architecture and 7 challenges (major technology areas)
   6.1. Functional description / performance targets / current situation / problem statement / way ahead
7. Represent graphically in a map
8. Value proposition for integrated development of Drilling Systems Automation Roadmap

Terms

Payment would be made monthly according to progress.

The intention is that the product becomes available to the industry. It is a compilation of input from a broad group who represent many companies from inside and outside the oil and gas drilling business.

The offer to the funding companies is:

- Early release to review the draft product in stages through an on-line website login page
- A one day workshop in Houston for all funders to discuss and debate the report as well as provide feedback to improve the report. Participants will also include key contributors to the roadmap.
- Early release of the report for internal use prior to release to the industry.