The International SKA Project: Industry Liaison Models and Policies

SKA Memo 80

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Executive Summary

The SKA is a large, complex project requiring significant involvement by industry at all stages, from pre-competitive R&D to operations. The Industry Liaison Task Force (ILTF) has identified projects which have some similarity to the SKA and finds that current large radio astronomy, other science and industry endeavours are all likely to yield lessons for the SKA in framing its industry engagement and governance models. This paper confines itself to looking at two radio astronomy projects (ALMA and LOFAR) but it extrapolates current experience to identify some of the issues, including trade and legal issues, associated with a very large international collaborations. It underlines the need to begin looking at procurement issues early in the project, to continue drawing lessons from a wide range of ventures, and to outline qualitatively and quantitatively the advantages and overheads involved in having industry deliver the SKA.

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1. Introduction

The international Square Kilometre Array (SKA) project is an enterprise aimed at delivering the largest radio telescope in the world. With a receiving sensitivity 10-100 times that of other existing and planned instruments the SKA – with its canonical 1 km^2 collecting area – is expected to be complete by 2020. The project is currently carried by an international consortium of 18 countries, with a project office reporting to a policy steering committee. Comprehensive science and engineering overviews are available (Carilli and Rawlings, 2004; Hall, 2004) and design goals have been summarized in SKA Memo 45 (2005). Details of management arrangements, timelines and many other matters are listed on the project's web site, www.skatelescope.org

From a designer's viewpoint the most challenging SKA specifications are its wide frequency range (0.1-25 GHz) and wide field-of-view (50 deg^2 at 0.7 GHz; 10 deg^2 at 1.4 GHz). A number of concepts have been proposed and prototyped, and recently the project has adopted a reference design incorporating elements of several of these. First-stage costing of the SKA indicates that a capital investment of at least €1 billion will be needed. Significantly for its delivery strategy, the project involves appreciable risk in meeting performance and cost goals, requiring the cost per unit collecting area to be reduced by a factor of 10 relative to existing radio telescopes and comparable systems.

One of the main SKA risk mitigation strategies is to stage the project. Broadly, the stages are:

- Development phase – construction and evaluation of SKA engineering prototypes, together with larger-scale scientific pathfinder instruments born within the SKA community but funded outside the project (2000-2009)
- Phase 1 - construction of a large radio telescope (~10 % of the SKA sensitivity) using the chosen SKA technology on the SKA site (2010-2013)
- Phase 2 – SKA construction (2014-2020)
- Phase 3 – SKA operation and progressive upgrade (post-2020).

The SKA will be an important scientific facility which is expected to make fundamental scientific breakthroughs. However, involvement in construction of the telescope will extend well beyond pure science: a world-wide community of only ~1000 radio astronomers and some 20 radio-astronomy technology centers means that delivery of the instrument necessarily involves very significant leverage via industry. In this respect, the SKA is similar to other mega-science projects, such as the Large Hadron Collider (LHC) soon to come on line within the High Energy Physics community. Of course, the specific technological drivers in the two instruments are quite different: in the case of the SKA two particular aspects driving close collaboration with industrial partners are the large numbers of antenna elements, and the huge signal transport and processing requirements. The scale of the SKA requires industry involvement in all project phases, from pre-competitive R&D exercises, through large-scale procurement, to facility operation.

Despite the similarity to some other science projects the SKA is different in one important respect. When the aggressive budget, timescale and industry leverage requirements are combined, it is clear that economical mass production and deployment will be a key element of the project. The implementation and operation of the SKA, and probably its ultimate specifications, will be influenced strongly by the imperative to align the project technology with volume (consumer) manufacturing and emplacement methods.

Industry involvement in the SKA needs to be framed within an international legal and business context and, despite an early emphasis on science and engineering feasibility studies, the International SKA Project Office (ISPO) and its Engineering Working Group (EWG) have recently formed an Industrial Liaison Task Force (ILTF) to examine industry interaction issues. The ILTF terms of reference and membership are summarized in Appendix 1. While the scope of the Task Force's activities will grow with time, this white paper is the first of its contributions. The main aims of the paper are to:

- Inform ILTF members and the wider SKA community about the importance of effective industry links, and the need to make early conscious decisions about the nature and extent of industry involvement in the project. (Priority is given to summarizing important policy areas and decisions which need to be taken soon);
- Outline briefly important aspects of the international legal and related environments in which the SKA project will operate;
- Examine projects comparable with the SKA and summarize their industry involvement policies;
- Explore the differences between costing models used in construction and operation of scientific and commercial facilities;
- Identify effective mechanisms for managing major industry involvement and managing mutual expectations over long periods of time; and
- Comment, from an industry liaison perspective, on SKA organizational and governance models proposed by the ISPO and its recently-established International Collaboration Working Group.

2. The SKA Project and its stakeholders

The main deliverable of the SKA project is a new astronomical instrument capable of transformational science. However, as well as the astronomers and astro-engineers associated directly with the project there are other important stakeholders, all of whom expect to gain from their involvement. These include:

- Governments, who wish to see financial and human capital returns, as well as knowledge creation, in sectors they identify as priorities;
- Industry, who not only wish to gain at least medium and long-term financial returns but who may have many additional motivations for involvement; and
- Academic research institutions, who wish to reap financial rewards (in a variety of forms), training opportunities and development of intellectual property.

These stakeholders are sometimes called the “triple helix” of collaboration (Langford and Langford, publication date unknown). Traditionally, the nature of the entanglement is held to be different in a science-led, rather than an industry-driven, project in that the guiding values change. It has been suggested by some (e.g. Ziman, 1994) that the value system in science-led projects embraces communalism, universalism, dis-interestedness, originality and skepticism. In industry-driven projects the underlying values are more likely to be proprietary, local, authoritarian, commissioned and expert. While this delineation of values may traditionally have held sway, values driving more modern collaborations can be more complex. For example, a particular corporation may choose to engage via a more or less pure research arm, effectively deferring the returns associated with conventional client-service business relationships. Still, it is useful to bear in mind that parties do often have different basic motivations for entering unions. One of the interesting key policy issues for the SKA project is whether it is necessary or desirable to shift from traditional science project values in order to fund and deliver the telescope.

Intellectual property (IP) management is an obvious area to consider when parties collaborate in a creative venture. In the international SKA project there is a need to manage IP both within the Consortium, and between the Consortium and external players, such as industry. IP management will be considered in detail in a future ILTF white paper but other main issues in collaboration are outlined in Section 7 of this document. SKA Memo 52, focusing on pre-competitive R&D, also canvassed issues related to intellectual property.

Before looking at specific SKA industry engagement aspects it is helpful to reflect on projects comparable to the SKA, both from a general and an industry liaison perspective.

3. Comparable projects

The SKA is a large, complex project with an international genesis. While it is difficult to define precisely the term “mega-science”, the SKA is fairly described as such a project since it fits at least one set of definitions (US OTA, 1995), namely:

- The projected cost of €1 billion is (just) comparable with “big league” science endeavours, such as the International Thermonuclear Experimental Reactor (ITER) or the Large Hadron Collider (LHC);
- The SKA involves large, interdisciplinary research teams which include both scientists and engineers;
- The project is supported by national governments, but industry has a central role because of the need to construct capital intensive, high-technology facilities; and
- It has, or will have, a noticeably more complex and hierarchical management structure than many smaller science projects.

The SKA clearly falls within the “big money plus big machines” brief definition of mega-science, and certainly constitutes scientific apparatus of “unusual size and sophistication”. Interestingly the SKA, in its full form (core, extended array, science centres, …) spans both the single-site and distributed classification sometimes attempted for very large projects. As with the SKA, proposals for many other large projects are generated by a “bottom up” process in which the scientific community plays a major role in setting an agenda, the implementation of which brings the project to fruition a decade or two after its inception.

Looked at in more detail, mega-science projects as a group are rather heterogeneous, and the variable science and social returns challenge national planners attempting to match cost contributions with returns in areas of national priority. While no other previous or planned project aligns exactly with SKA challenges, there are projects which, by virtue of their characteristics in particular areas, have relevance to the SKA. For comparative purposes attributes for adjacency to the SKA project might include one or more of the following:

- Relatively large scale and cost (at least €100M)
- Substantial budget and/or performance risk
- Multi-national, preferably in astronomy or another science domain
- Substantial industry involvement in the project delivery, preferably with industry links persisting throughout the project lifetime.

In future work the ILTF intends to look closely at large projects spanning a range of fields. In particular, large international optical telescope projects will be relevant, although most do not engage industry in much pre-competitive R&D nor, by the nature of the instruments, does later engagement during construction involve mass production. Outside astronomy, the ILTF plans to look in particular detail at high energy physics (HEP) projects. More recent HEP undertakings typically have a higher level of pre-competitive R&D than astronomy projects and, at least for some key components, feature higher levels of replication. In this first ILTF contribution, we look at two current projects in the field of radio astronomy: ALMA and LOFAR. For conciseness, overall project summaries are given in Table 1, while Table 2 contains more details of industry liaison.

The SKA can learn from the industry interactions of both ALMA and LOFAR, but the SKA imperative of mass production and fast deployment leads to a particularly close association with the LOFAR model. LOFAR was, of course, born in the SKA mileu and, while the project is a tenth the scale of the SKA, it is notable because the nature of LOFAR has been influenced heavily by industry's interests, and by the capacity of industry to deliver timely, cost-effective solutions in key technology areas. Important sub-systems, such as the supercomputer-based correlator, have only been made possible by collaborative R&D with industry. Still, while there has been a strong motivation to use "off-the-shelf" solutions where possible to speed project delivery, specialist development by the host institute has been required in areas such as overall system design, antennas, RF systems, and calibration/imaging schemes. LOFAR has a strong emphasis on prototyping and risk mitigation via fall-back options, having recognized that, as in the case of the SKA, such a model is the only credible way of retiring risk when development and delivery timescales overlap.

At the time of writing LOFAR is incomplete and full evaluation of the project model is not yet possible. However, first results from the software correlator – perhaps the boldest departure from conventional telescope architecture – point to success, largely because of effective nurturing and management of industry collaboration with a partner able to supply know-how not originally present in the radio astronomy community. For IBM, the industry partner involved, the engagement follows the 'modern' collaboration values mentioned in Section 2.

ALMA also features a level of pre-competitive engagement with industry but, where external R&D has occurred, most of it has been done via conventional contracts. This contrasts with the LOFAR situation, where there has typically been a high level of joint involvement in R&D collaboration between the science and industry partners, a model likely to be needed to deliver the SKA on the current aggressive schedule. Perhaps the main lessons from ALMA are in the area of project structure and the need to establish effective, authoritative, international management of both general and industry matters early in the endeavour (Section 6).

Emphasis on pre-competitive R&D collaboration does not of course diminish the importance of industry in more conventional manufacturing arrangements. Specialist systems and components developed within the SKA community will need to be passed to industry for large-scale manufacturing under straightforward contract arrangements. This is the model used for the LOFAR antennas and it might also be used for SKA components developed within, for example, other major pathfinders such as the Allen Telescope Array. In this type of industry interaction domain the SKA is on firmer ground in being able to learn from other projects, including ALMA.

Even though both ALMA and LOFAR have significant “pre-history” which is not completely summarized in Tables 1 and 2, just considering the lifetimes of the formal projects is sobering from an SKA perspective. ALMA, a large radio telescope at a remote site, will take at least a decade to deliver despite occupying comprehensively premier global astronomy institutions throughout that period. LOFAR, a tenth-scale SKA using innovative thinking and new-generation system design will be more than five years in the making. To bring the SKA into operation by 2020 will clearly be an enormous challenge, a challenge that can only be met by an ability and willingness to engage industry at hitherto unprecedented levels.

Nothwithstanding lessons from other science projects, this high level of industry involvement makes it imperative that SKA planners are familiar with delivery models for multi-billion euro industrial and infrastructure projects. The costing models for these projects are very different to those in most science endeavours and, just as the SKA may accept poorer individual component specifications to accommodate consumer technology and mass production, it may also accommodate higher delivery overheads in order to complete the project on a feasible timescale. Describing and, as far as possible quantifying, these overheads will form an important part of the ILTF’s continuing role.

Table 1 – Summary of two large radio astronomy projects

	Atacama Large Millimetre Array (ALMA)	**Low Frequency Array (LOFAR)**
Description	Sixty-four (initially) antenna synthesis radio telescope under construction by international collaboration. Regional centers in US, Europe, Japan and Chile provide access to the instrument for astronomers.	Seventy station, 30-240 MHz synthesis radio telescope. Key SKA pathfinder in areas such as software-defined signal processing, RFI mitigation, multi-field observing and industry interaction.
Location of facility	5000 m elevation site in Atacama Desert, Chile	Central core near Exloo (Netherlands), with stations distributed across NL and Western Europe
Initial concept date	~ 1982; 1992 US recommendation to fund MMA.	~ 1997, with project activities starting 1999.
Initial proponents	NRAO (USA), ESO (Europe), NOAJ (Japan)	ASTRON (NL), NRL (USA), MIT (USA)
First budget projection	USD 500M (2002 dollars)	€25M for a 10-90 MHz instrument, grown into a €150M facility as the science case expanded
Major concept milestones	1999 – US Millimeter Array and European Large Southern Array merged to form ALMA.	2000 – High band (110-240 MHz) added; choice for “software correlator”. 2003 – Adopted “multi-disciplinary sensor network” to broaden use of antenna stations.
Major funding milestones	February 2003 – Bilateral funding agreement between NSF and ESO.	2001– Initial design studies funded (ASTRON, MIT) November 2003 – Final design and construction phase funded.
Main funding application submission date	Design and development – late 1990s. Construction – 2002.	2000 – Proposals for initial design studies submitted to SNN (NL) and NSF (USA). 2001/2002 – Construction funding requested in several proposal rounds.
Formal proponent(s)	NRAO, ESO	ASTRON-led consortium involving universities and industrial partners.
Funds requested	USD 562M	€ 150M

Funds approved	USD 562M (split between development and construction phases).	€ 83M + € 83M matching from consortium partners and various other agencies.
Project management arrangements	Collaborative model, central Project Office providing technical and strategic co-ordination.	Final design and prototyping carried out by ASTRON in collaboration with universities and industry partners, (both SMEs and large industries including IBM). Final project delivery and operation by newly-formed legal entity (LOFAR Foundation).
Major funding agencies	US National Science Foundation, ESO	Government of the Netherlands via several national and regional programs (BSIK, SNN), involving both the Ministry of Education and Economic Affairs.
Main funding application approval date	February 2003 – Bilateral funding agreement between NSF and ESO.	November 2003
Main project start date	November 2003 - Groundbreaking	January 2000
Project headquarters	Santiago, Garching, Charlottesville	Dwingeloo, NL
Major project stages	Site Construction 2002-2011. Antenna construction 2005-2012.	1999-2003: preliminary design. 2004-2006 final design. 2006-2008 Roll-Out. 2007 Initial Operations.
Completion date	2012.	2009
Formal milestones (selected)	2002: Baseline array defined 2004: Re-baselining (40-50 ant.) due cost increases 2005: Approval draft operations plan 2005: System requirements review 2007: ALMA project CDR complete	Oct 2002: SRR March 2003: PDR 2005: Subsystem CDRs; Sept 2006: System CDR; 2007 Initial Operations
Non-recoverable engineering costs (estimated)	10% (to be confirmed)	€38M (excluding industrial matching)

Operations model	Regional centres provide face to astronomy community. Joint ALMA Observatory overseeing array operations.	Multi-tier model with LOFAR Observatory and university-based Science Centers. Key science programs and peer reviewed open access via LOFAR Foundation
Managing organization	NRAO, ESO	ASTRON (initial), then LOFAR Foundation
Countries involved:		
Initially	USA, Europe, Japan	NL, USA (AU, 2003)
At main proposal	USA, Europe	NL (only NL funding granted)
At completion	USA, Europe, Canada, Chile, Japan (since 2004), Taiwan	NL, Germany, possibly France, UK, Sweden

Table 2 – Industry liaison summary

	Atacama Large Millimetre Array (ALMA)	**Low Frequency Array (LOFAR)**
Significant pre-competitive R&D involvement?	Yes	Yes
Major areas of pre-competitive R&D	Low noise amplifiers and receivers. High-precision antennas (surface & pointing). High-bandwidth digital data transmission. Photonic reference signal distribution.	High performance computing (HPC), high speed networking, low cost mass-produced antenna technology, low noise amplifiers, direct conversion receiver chain, high speed embedded processing (hardware, VHDL), signal processing algorithms (RFI mitigation), new calibration schemes;
Technology transfer mechanisms	Existing IP transfer schemes for organizations involved; nothing ALMA-specific.	Consortium agreement handles IP between consortium partners. Individual bi-lateral R&D Collaboration and Non-disclosure agreements with other partners.
Principal pre-competitive industry partners	Vertex, Alcatel	IBM, Lucent, Xilinx, S&T, DutchSpace
Procurement model	Tender (bid), review, award	Industry briefings followed by formal tender prodedure following European procurement law
Major contracts	Vertex, Alcatel (antennas). Scheurle (transporter). Con Pax (site buildings).	IBM for Blue Gene/L supercomputer (in context of research collaboration). KPN (NL telco) and others for wide area networks. Xilinx for FPGAs. Various smaller contracts for subsystems
Legal jurisdiction	Operates under international agreements associated with executive partners.	European Union, NL

4. Industry interest in the SKA

There are many reasons why companies may wish to be associated with the SKA. These range from short-term financial gain via prototyping contracts in the Development Phase, through to more indirect motivations such as a wish to develop staff in ways not routinely available. An earlier paper (SKA Memo 52), listed reasons encountered so far in the SKA project, including:

- The opportunity to grow and hone the creative energies of the best professionals in a highly imaginative project;
- The ability to perfect leading-edge techniques and products in a very demanding application, and to interact with technologically sophisticated users;
- The ability to generate and share information with other R&D partners – both institutional and industrial – in a benign and commercially non-threatening environment;
- The visibility flowing from association with an innovative, high profile, international mega-science project;
- The potential for early involvement and, directly or indirectly, favourable positioning in a € 1 billion project spanning a wide range of engineering and computing disciplines; and
- The opportunity to apply, for financial gain via negotiated licence agreements, IP generated within an SKA partnership to commercial activities outside the SKA arena.

In noting that initial SKA – industry interaction was via Development Phase national and regional demonstrators, SKA Memo 52 exams challenges in establishing and managing pre-competitive collaborations. It also shows a matrix of possible areas for early collaboration for various national groups. While some early industry participants see themselves as predominantly Development Phase players, others are definitely interested in larger-scale commercial involvement in Phase-1 and Phase-2, or in operating and maintaining the SKA in Phase-3. Of course, the scale of the SKA project requires significant industry participation on all timescales.

Much initial industry interest is understandably associated with the SKA being located at a particular site. One study (cited in US OTA, 1995) found that 40-70% of funds used to operate large international facilities are spent in the host nation. Hosting the SKA will undoubtedly give local companies an advantage during infrastructure construction and facility operation. However, potential industry and government participants now appreciate that the more knowledge-intensive components of the instrument will be developed and procured in many different countries. In calculating equitable returns (*juste retour*) for global partners, contracts to deliver ground-breaking or leading-edge technologies may be therefore be more attractive than hosting to some governments, given their potential to build new sectors and generate economic activity.

It is already clear that care will be needed if early participants in the SKA project are not to be later excluded on the basis of, for example, regional or international procurement regulations aimed at anti-competitive behaviour. The next Section examines a few principles of procurement while subsequent Sections attempt to translate the legal principles into some general strategies for managing industry involvement.

5. SKA procurement – preliminary considerations

5.1 INTRODUCTION

5.1.1 Scope of these considerations

It is still too early to give detailed and concrete proposals for how SKA procurements should be carried out. More will have to be known about the shape of the activities. It is not too early, however, to start thinking about the problems. This Section does not pretend, therefore, to be a coherent blueprint or handbook for procurement for SKA but rather tries to bring to the fore the major issues that will have to be addressed. It covers some of the same ground as SKA Memo 52 (2004), but not on a point by point basis. It tries to emphasize problems and to provoke discussion rather than to give a comprehensive summary or procurement for all parts of the world– which would in any case require a bookshelf and a number of specialists.

5.1.2 A remark on terminology

In the context of public (regulated) procurement laws, the term procurement refers to the process of issuing calls for tender[1], the process of evaluation and the granting of a contract. The term can also be used, in a less legalistic way, to cover the whole process, starting from establishing the requirements, to placing the contract, perhaps monitoring the contractor's progress, receiving delivery and even dealing with maintenance and guarantees. This reflects the view that it is a more or less seamless process from beginning to end. What is done in the early stages sets the framework for the later events, and the basis for a successful project, rather than one with cost overruns or technical failures, is largely determined by taking a "whole project" view from the outset. Unless the context makes it clear otherwise, the term "procurement" in this memo refers to the broader meaning.

5.2 PUBLIC PROCUREMENT RULES

Public procurement is the contracting for works, goods and services by a government or by a subsidiary governmental body, such as a local authority, or an organization predominantly funded or controlled by a government, such as, perhaps, a hospital, university or research institute. This procurement is now heavily regulated by law – the European Procurement Directives, the World Trade Organization rules, national legislation, and requirements of such bodies as the World Bank or the IMF etc. Some countries have based their laws on the

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[1] Terminology varies – calls for tender, requests for offers, requests for proposals, requests for quotation and so on. There are no subtle distinctions, only cultural linguistic differences.

UNCITRAL model laws. While the rules are by no means identical, they have major points of commonality, in particular that there must be fair and open competition, non-discrimination, transparency and the availability of remedies for non-compliance.[2]

There are some exceptions to the application of the rules – contracts below a certain financial threshold, pre-competitive research contracts, contracts where only one contractor is capable of performing the work, emergency and defence contracts.[3]

The usual reasons given for strict regulation of procurement are to provide a level playing field for an open market, and to prevent corruption. (The balance between these two varies according to where the activity takes place). The rules entail a considerable degree of formality and are often seen by both the purchasing body (the Contracting Authority) and the bidders as little more than an expensive nuisance. There is, however, a third reason for having such rules – usually somewhat underplayed by lawyers – namely that much of what is in the rules leads to a more successful project, in terms of quality, price and timely delivery. This is frequently termed “best practice”. The resentment felt by participating parties when their efforts first fall within the regulations, and restrictions and formalities apply, tends to lessen as they become familiar with the procedures and see the advantages as well as the constraints.

5.3 FAIR COMPETITION

There are a number of rules that are designed to ensure fair competition. They concern aspects of procurement that also have wider implications than the mere formal maintenance of balance between the competing suppliers, and relate to qualitatively good procurement. The discussions below therefore also refer to these other aspects.

Specifications/requirements

The rules about specifications state that they must not be written in such a way as to give one bidder an unfair advantage over another. They must not, for example, require the use of a particular piece of equipment from one supplier if other suppliers could provide an equivalent. They must not demand the use of intellectual property which is in the hands of only one bidder.[4] The ways in which specifications or requirements can be biased

[2] Detailed information on the various procurement rules in different parts of the world will have to be sought at a later stage from experts, when the pattern of procurements is better known. It will be advisable to maintain a degree of visibility at the SKA program level, to ensure coherence.
[3] This list is illustrative, and not to be taken as full statement of the law.
[4] There are, of course, exceptions to such rules if there is an overwhelming objective justification.

can run from the crude to the extremely subtle – but all can be challenged by other bidders. Examples include using purely national technical standards, requiring the use of sand from a particular source for cement, or referring to information not generally available. In particular, a potential bidder should not be actively involved in is establishing the requirements.

Prior involvement by a supplier

A potential bidder should not be given foreknowledge of requirements that give him a technical or commercial lead. The most extreme example of this is when one of a number of potential bidders for a contract has already been given a contract for a prior phase of the work. The advantages are obvious and range from better understanding of what will be needed to the possibility of developing hardware (whether funded by the customer or not).

Limitations on contact

It is good practice to avoid contact between the personnel of the contracting authority and potential bidders, once a procurement action is underway, in order to avoid suggestions of partiality or the leaking of information. This is not always easy, as there is often running contact on a number of different issues. On the other hand, industry is shameless in trying to extract information. A culture of internal discipline must be developed in a CA.

These rules pose major problems for large scale, long term scientific projects which involve considerable development, with the need for a range of studies, pre-developments etc. The public procurement rules have not been written with much attention paid to, or understanding of, the specific needs of such projects. A good example of this is the prohibition on negotiation with bidders (see Section 5.8). Where a company is involved in an early (and vital) stage of the project (such as a preliminary study or pre-development) there is a risk that it might be excluded from subsequent participation precisely because of its prior knowledge. It seems perverse to exclude from the early stages of a project precisely those organizations that have specific relevant knowledge or skills. This situation creates difficulties for the very necessary “potential for early involvement and favourable positioning in a $/€ 1 billion project spanning a wide range of engineering and computing disciplines”. It is possible to operate properly within the rules and still do what is technically and scientifically necessary – after all projects are successfully completed – but it does require a lot of care, forethought and advance preparation in formulating a broad procurement scheme.

Among the approaches to be used one can mention:

- When placing a study or technology development contract, do this on the basis of a competition, thus providing a justification for continuing relations with the contractor.
- It is sometimes possible to place a study with a provision that the results will be made available to all potential bidders for the main contract.
- Parallel competitive studies, notwithstanding the additional expense, can sometimes produce better results, as well as justifying the further selection of one contractor.
- The most useful input at an early phase might be from contractors who do not have the capacity or desire to engage in large scale manufacture. A condition for taking one of the preliminary contracts can be that the contractor agrees to make himself available as a potential sub-contractor to any future potential main bidder with an industrial production.
- In extreme circumstances a developed technology that is regarded as vital can be treated either as customer furnished equipment or as an imposed sub-contract. This has the disadvantage that it entails considerable customer responsibility for the results.

The last two points can be useful elements for achieving some degree of *juste retour.*

5.4 THE CONTRACTING AUTHORITY (CA)

In the SKA project it is possible that there will be more than one (regional) body responsible for procuring a part of the overall SKA program. Each such CA will have to be a legal body, capable of entering into binding contracts. Each body will, within the regulatory constraints, wish to procure according to its own known practices and procedures. At the same time there will be a need to coordinate a number of elements between the different CAs. Intellectual property rules have already been identified. A number of other contractual clauses should as far as possible be, if not identical, then at least with the same effect, as should the bidding and evaluation procedures. Discussion is needed as to the role of the SKA program office vis-à-vis the different CAs is needed. Similar issues apply with regard to technical standards, interfaces etc.

The degree to which a contracting authority takes an active role in the procurement once the contract is placed has a far-reaching effect on many elements. At one extreme the requirements are expressed purely in terms of performance and the CA takes a hands-off approach till delivery. At the other extreme the CA is virtually a consortium leader – it acts as design authority, continuously monitors progress, technical, cost and schedule, and insists on changes during the work if not satisfied.

The choice of approach is partly one of procurement philosophy (or fashion), and partly an objective one based on the nature and needs of the project. The mode over the last years has been towards a “hands-off” approach (in line with general economic thinking – privatization, out-sourcing etc.) It is often stated (though this can be disputed) that this approach leads to greater efficiency and lower costs. It can be seen as assessing the risk at the outset, attaching a cost to this in the price and then putting the risk on the contractor.

A different view is sometimes held for projects with a large development element, long duration and contractual complexity (e.g. many subcontracts). Arguments for a more hands-on approach are that it is impossible to assess and cost the risks at an early stage with sufficient accuracy to put a reasonable price on them, that over a long period changes will occur cannot be properly foreseen in a fixed price, and that, especially in a scientific program, the drive is towards excellence and maximum performance rather than just meeting a specification.

It is sometimes claimed that this manner of procurement is expensive and inefficient. It is true that it puts a significant degree of development risk on the CA, and requires that he exercises self-discipline and is capable of doing a proper and effective job of project control. Without that, it is indeed an ‘open cheque’. On the other hand a CA who has in its hands the appropriate knowledge and experience can ensure that the development process is better steered towards meeting or exceeding the project requirements than would otherwise be the case.

Of course neither approach is absolute – and one of a range of contractual solutions can be selected from between the two extremes. Nor need the role of the CA remain the same during the whole project. It can begin as an interventionist (or collaborative) approach, and at a certain time, when requirements and technical solutions are reasonably frozen, move towards a more distant relationship. This is a major element in adopting a phasing policy.

5.5 PRICE TYPES

Similar considerations apply to choosing an appropriate type of price. Again, procurement fashion also sometimes overrules an objective assessment of the proper approach. In a fixed price contract the contractor takes on all the risk and, of course, includes this in his price. This has the advantage of (sometimes illusory) certainty for the CA. If the risk is large (say more than about 10%) the price becomes unnecessarily high, especially if there is no real competition. If the contractor has underestimated the risk, then he will be tempted either to cut corners to reduce cost, or engage in an effort to get over-compensated for changes. This will work in a particularly detrimental way to a complex scientific project. The danger is particularly high if an artificially low fixed price is agreed with a view to getting program approval, under the assumption that once work is committed more funds can be prised loose. A macho posture does not always reflect real vitality.

A cost-reimbursement price can be seen as an open cheque, with an undetermined end-point, and is particularly disliked by the providers of the project funds, who like budgetary certainty. There are, however, techniques for controlling costs, including active project control and the use of target costs and cost-incentives. Managing such a contract does demand greater resources and responsibility of the contracting authority.

On balance, one can say that if the unknowns (such as lack of clear definition of requirements, uncertainty of technical solutions, anticipated changes, timescale, external interfaces, political pressures) are greater than (say) 10%, then a cost-reimbursement contract with protective clauses will work best. If the unknowns are not excessive, then a fixed price has advantages.

5.6 PHASING

The above remarks suggest that a proper phasing policy will allow a better flexibility in the procurement process and will allow changes in the approach over time to extract the maximum benefit to the project without infringing the rules. Phasing has, of course, many other functions, and this is not the place to discuss them. A few comments might be useful in the procurement context.

- The classic phases (feasibility, design and development, detailed design, manufacture, commissioning, maintenance, or variations on these) should apply to individual projects within the overall program.
- Each phase should end with a clearly defined output, including where appropriate a price offer for the next phase. It is bad practice to authorize the start of a new phase before satisfactory completion of the previous phase – cutting metal before having an agreed design. Pressure to do this often arises from budgetary or political pressures, and leads almost inevitably to cost overruns at a later stage.
- There should be a good coherence between the phases of an individual major element and the overall program, and between the technical phasing and the budgetary availability. Lack of coherence leads to distortions which lead to additional costs.

5.7 EVALUATION

Regulated public procurement requires that competitive bids be evaluated according to formal procedures, against pre-determined criteria. In the majority of procurements there is a technical evaluation and the contract is then awarded to the bidder with the lowest price. This somewhat simplistic approach is not appropriate to scientific or very complex procurements, where the best combination of technical excellence and price should determine the selection. If the contracting authority does not already have established evaluation procedures it should set them up and instruct its personnel in their operation. Clear identification of the authority which can approve the placing of a contract is also needed.

5.8 NEGOTIATION WITH BIDDERS

In general the procurement rules prohibit negotiation with bidders during an evaluation process (except in a special procedure known as best and final offers – BAFO, which is more a repetitive bidding than a negotiation). They also prohibit negotiation after placing the contract – the idea being that this changes the ground rules on which the selection was made. It cannot be expected that a bid of the sort one expects for a project such as SKA will be optimal in all aspects, nor does it make sense to place a contract with elements which are known to be capable of improvements. In practice discussions do take place. If prior to signing the contract they must be "in scope" and sufficiently restricted that it cannot be claimed that competition was distorted. If this is so, a challenge by another bidder is unlikely. Of course proprietary data of other bidders must not be passed. Improvements after placing the contract should be subject to a rigorous contractual modification procedure

5.9 CONTRACTS

SKA Memo 52 addresses the issue of the contracts to be placed, in particular at the early stages of the program, and pleads for a "light legal touch". To a certain degree a lawyer has to take exception to this.[5] An MOU constitutes either a binding agreement or it does not. If it does (as it absolutely should) then it is a contract. The only difference is the name. The list provided of what should be in an MOU is more or less complete. Whether certain issues (such as commercial utilization provisions) should be addressed from the outset is to be decided on a

[5] In fact, a lawyer might agree with almost all that Memo 52 says, other than the particular conclusion. The issue of the contents and way of drafting the contracts is vital, and perhaps somewhat unfamiliar to many participants. Familiarization with, and discussion of, the issues should be extensive and start soon, so a lawyer's job is to take a somewhat provocative stand and look forward to an amiable exchange of polemics, whereupon we should find that there is no significant disagreement.

case by case basis. The test is whether failing to deal with it could provoke uncertainty or dispute at a later stage. Avoiding an identified issue can be dangerous. Sometimes a general principle can be agreed and amplified at a later date. That said, there are provisions that are only appropriate to a later phase, such a detailed modification clauses and control procedures which are not needed until specifications and prices are fairly fixed. “Legal weight” is more the product of inelegant drafting and the inclusion of irrelevant boilerplate text and repetitious statements. There is no reason why a contract cannot be clearly drafted, easy to understand and capable of reflecting the actual intents, rights and obligations of the parties – though frequently it is not. The same applies, however, to specifications, project plans, standards and other more technical documents, which are part of the contract. Much of the value of a contract lies in the discussion and negotiation. A good contract (reflecting a good relationship) will usually stay untouched on the shelf once signed.

5.10 PROCUREMENT PLAN

It is recommended that a procurement plan be established at an early stage. Such a document should cover all aspects of the intended procurement actions in such a way that industry has a clear view of what is going to come up, and when, and can prepare itself. It also allows, where appropriate, for public authorities to consider the plans and concur that they meet the regulatory requirements.[6] An internal version, containing additional information not suitable for passing to industry (e.g. assessment of the competitive situation), can be made for the project.

[6] For example, the LOFAR procurement plan was submitted to regional, national and European authorities for comment. This was almost certainly a contributing factor to the smooth functioning of the first major procurements in the project. The plan was also made available on the Website.

6. Strategies and models for industry involvement

One of the inferences to be drawn from the previous Section is that industry involvement with the SKA must be both bounded (well-defined) and traceable, in the sense that input and returns must be transparent. The scale of the involvement will range from the very small (e.g. supply of minor components) to the very significant (supply of major items, such as antennas) and the links will come in many forms, from service provision to specialized manufacturing. Ultimately, industry involvement needs to deliver performance and value to the SKA project, while satisfying a host of national and regional expectations.

Experience with other international projects shows that it is necessary to balance the efficiencies that come from highly centralized planning and management against the flexibility needed to successfully implement sub-systems and components (US OTA, 1995). In addition, some projects are especially amenable to modular designs, allowing collaborators to focus on specific goals and to work within defined interfaces to the overall system. Others, like the early stages of the LHC, require partners to adopt a much more integrated approach, with a commensurate increase in management overheads. The SKA has elements of both: a tightly integrated international specification and development effort but the potential for modularizing many Phase-1 and Phase-2 tasks.

There are of course additional considerations concerning national investment levels, fair financial returns and eventual access to SKA observing time, and it is clear that the SKA project cannot re-invent existing trans-national legal and trade agreements. The project is therefore faced with a structure having the following elements:

- Division into deliverable modules or “chunks” corresponding, in some cases, to telescope sub-systems
- As far as possible, alignment of these chunks with national and regional expectations
- Co-ordination of the international legal, engineering and, eventually, operational aspects of the collaboration via a project office or similar body.

As mentioned in Section 3, the ALMA experience leads one to infer that such a model works best when the chunking is done early in the project and when there is a strong international project office active in managing the project from its early stages. ALMA will mix two, apparently equally-qualified, antenna types to be supplied by European and US manufacturers, a sub-optimum outcome from at least an engineering perspective. SKA needs to avoid the situation where early-stage industry engagement in a technical demonstration leads to a loss of freedom in optimizing production design choices. While the present suite of regional demonstrators is well quarantined from the SKA, development and demonstration of an international design will require careful structuring and management.

Given the breadth of the International SKA Project Office (ISPO) activities a key practical question relates to the legal standing of the Office and its relationship to either a new or existing umbrella organization charged with delivering the SKA. From the industry perspective, a major function of the ISPO is certainly to develop and promulgate broad guidelines for regional SKA participants. At the implementation level though, local variations in contract and related law make it more efficient to have regional entities administering particular sub-projects. The real challenge is to find the optimum structure for the intermediate layer, wherein broad policy is interfaced to regionally-devolved work packages.

The industry leverage required to build the SKA is so great that the ISPO cannot be responsible, in an executive sense, for delivery of the project. More likely, the ISPO would, on behalf of the SKA community, engage a prime contractor, familiar with implementation and supervision of international contracts, and with integration engineering in a very large-scale project. Factoring in the requirement that the SKA community retains control of the project direction leads to a model such as that shown in Figure 1. Here, project policy – including industry policy – is generated in, and promulgated by, the ISPO and regional SKA project offices. At the same time, delivery of the Telescope is the responsibility of a prime contractor supervising a number of international work packages, themselves the responsibility of co-ordinating regional contractors. An important feature of the arrangement is that, while there are strong links to the business community between the ISPO and regional offices, drafting and supervision of legal agreements is done by experts at the international and regional levels.

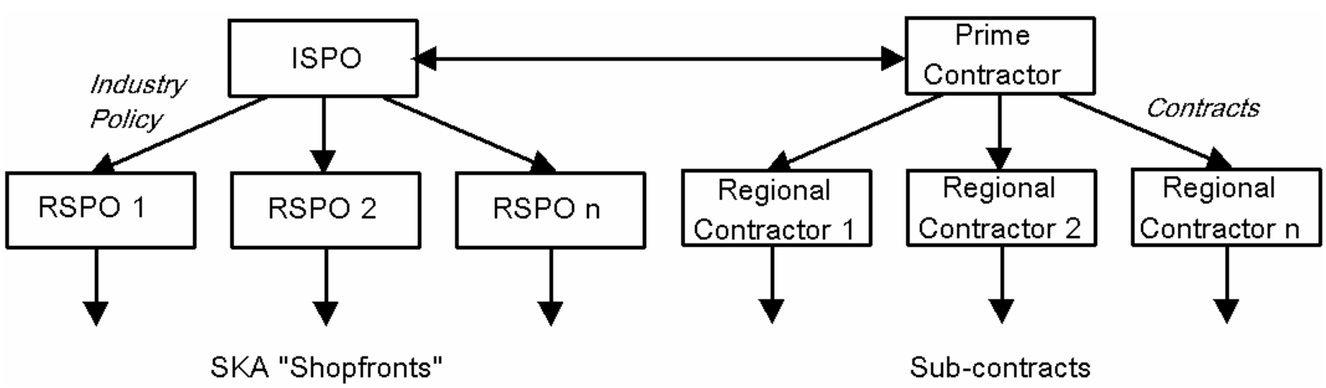

Figure 1. Possible SKA project model showing division between industry policy and executive function.

Undoubtedly there are other project models which will work; we see the arrangement described above as just one workable representative structure in which policy and engineering are separated, and where regional contracts and work packages are administered by those best-placed to guarantee smooth operation and quality outcomes.

7. Managing industry interaction

7.1 INTRODUCTION

This section covers some specific collaboration issues currently facing SKA Consortium members. Many of the topics will need to be covered in greater depth as the experience of the SKA community increases and as expertise from a wide range of sources is folded into the project. Nevertheless, these first general comments are likely to be useful to members engaged in drafting collaborative agreements with industry, or other external partners.

7.2 INTELLECTUAL PROPERTY

One of the most significant concerns in any collaboration, whether involving industry or not, is that of intellectual property (IP). IP has been defined (e.g. Wikipedia, 2006) in the following terms:

“A legal entitlement which sometimes attaches to the expressed form of an idea, or to some other intangible subject matter. This legal entitlement generally enables its holder to exercise exclusive rights of use in relation to the subject matter of the IP. The term *intellectual property* reflects the idea that this subject matter is the product of the mind or the intellect, and that IP rights may be protected at law in the same way as any other form of property”.

IP within a collaboration can be grouped into foreground and background components, where the former is created in the course of the collaboration and the latter is brought into the project by the participants. Under the terms of the SKA Statement of Common Intent on IP, all Consortium members undertake to make exclusively owned foreground IP available to the SKA project free of charge. However, members are free to exploit such IP for profit in areas outside the SKA project.

As the SKA does not yet exist as an international legal entity, any collaborative agreements with industry must currently be made between legally responsible Consortium members and similarly competent external partners, such as companies. A template agreement developed recently by the ISPO for use by Consortium members contains a number of provisions designed to protect all parties and, ultimately, the international SKA project. This agreement addresses the major concerns relating to future SKA procurement activity (Section 5) and to IP issues.

In broad terms the most challenging IP issues arise when an SKA Consortium member and an external partner both own, probably by virtue of joint development, IP which is potentially applicable to the SKA. In legal terms such ownership is unfettered: each party may exploit the IP entirely independently if they wish, without agreement from the other party. This exploitation can even be competitive in that both parties, or their licensees, can seek to independently and simultaneously profit from the IP. If the SKA Consortium member is unable to exploit the IP, the Consortium may find itself paying commercial rates to a licensee of its partner for products containing IP generated in the course of the external collaboration. While apparently undesirable, the alternative may be to not have the product available at all, perhaps to the detriment of the SKA.

Only a small fraction of collaborations are likely to lead to this “worst case” outcome. The LOFAR experience, for example, is that collaboration has led to little joint IP; most new material is owned by one or other of the parties. Furthermore, while there is no ultimate legal imperative to co-ordinate exploitation of joint IP, in practice it is often in the interests of both parties to do so. Finally, even in the event of the SKA having to license back a product or process, it may be possible in some circumstances to arrange in advance for the licensing to be done under commercially attractive terms. It is also worth bearing in mind that the joint IP ownership provisions can, of course, just as easily work to the advantage of the SKA. The project could find itself being able to use valuable new IP while being free to license (for profit) application of the IP outside the SKA.

7.3 REGIONAL SKA DEMONSTRATOR AND PATHFINDER PROJECTS

Apart from their enormous science and engineering importance, regional demonstrator and pathfinder projects offer a way of involving industry in critical R&D needed for new-generation radio telescopes. At the same time, they potentially allow a high level of isolation of the international SKA project from early commercial entanglements which could complicate later processes such as procurement.

There are two aspects of demonstrator/pathfinder projects which currently require the attention of the ISSC. First, it is desirable that the SKA Consortium state explicitly that its existing Statement of Common Intent on IP, or some amended version thereof, applies to these projects. This will simplify greatly the working relationship of members over the next few years, as well as providing a solid and easily-explained collective stance to members wishing to collaborate with outside parties, including industry. Second, it is important that external partners in regional projects be informed explicitly that their involvement is not with the international SKA project. Furthermore, partners should be made aware that, if regional consortia or their associates wish to bid during the SKA procurement phase, it may be necessary for parts of newly-developed IP, including joint IP, to be made publicly available during the tendering process.

The ISPO template agreement for industry collaboration (Section 7.2) assumes a clearly enunciated position from the international SKA Consortium with respect to transfer of its members' IP, separates the demonstrator and SKA projects as far as possible, and mentions explicitly the possible IP revelation requirements during the SKA tendering processes.

At a procedural level, agreements with external collaborators should define tightly the areas of collaboration, set out clearly the background IP of the parties involved, and note explicitly an operational lifetime for the agreement. Agreements should also cover the issues of foreground IP, joint IP and licensing. In most cases the provisions of the ISPO template agreement will be transferable, at least in broad terms.

8. Future industry liaison work

We identify several areas in which significant future work is required. Most areas will require specialist input from individuals or groups currently outside the SKA circle, raising challenges related to finding the right advice and paying for it. Broadly, the new work divides into technical and non-technical areas, with the following tasks being identified as especially high priority:

- Casting the SKA Reference Design into a form suitable for final development, production and deployment by industry. Associated tasks involve estimating any performance sacrifices inherent in industry delivery of the project, and estimating an all-up cost for SKA Phase-1 and later stages. This work, which needs to begin early in the SKA Phase-1 design process, has a large technical component and requires significant co-ordination of radio astronomy and production engineering expertise.

- Further exploration of intellectual property and associated licensing issues by the SKA project and its legal consultants. This work will be linked closely to regional pathfinder projects in order to capture experience and expertise generated within these endeavours.

- Armed with a clearer picture of SKA siting, technology and project participation (at least for Phase-1), generation of an initial mapping between participants and deliverables ("chunking"). This will require the involvement of consultants operating on behalf of the SKA, and of legal and trade experts from the government agencies which are currently increasing their interest in SKA.

- Production of an industry involvement plan for SKA Phase-1 based on agreed technology choices and regional deliverables. This will need the involvement of large, internationally experienced, engineering and project management consultancies; it could, and probably should, be done in conjunction with companies likely to be short-listed as SKA Phase-1 project managers. One important product of the plan should be a clear summary of the on-costs involved in meeting the accelerated project delivery required by the current SKA timeline.

- Continuing examination of large industrial and infrastructure projects with a view to distilling lessons and costing estimates for an SKA delivered by industry on an accelerated timescale.

- Drafting of a specific SKA procurement plan, taking into account the outcomes of the studies mentioned above. While the plan may not be able to be finalized for some years, the process of drafting it will be valuable to those optimizing the structure of, and interactions within, the project.

Acknowlegements

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References

Carilli, C. and Rawlings, S., New Science with the Square Kilometre Array, *Astronomy Reviews*, Vol.48, Elsevier, 2004

Hall, P., The Square Kilometre Array – An Engineering Perspective, Experimental Astronomy, Vol. 17, Nos. 1-3, Springer 2004.

Langford C. and Langford M., University, Industry, Government Relationships in Canadian Access to Megascience Research Environments, University of Calgary, date unknown. Available at: http://www.chem.ucalgary.ca/groups/langford/megasci.htm

Office of Technology Assessment, International Partnerships in Large Science Projects, US Congress, OTA-BP-ETI-150, Washington DC, July 1995.

Wikipedia, Intellectual Property, 2006. Available at: http://en.wikipedia.org/wiki/Intellectual_property

Ziman, J., Prometheus Bound: Science in a Dynamic Steady State, Cambridge University Press, 1994.

Appendix 1 – Industrial Liason Task Force (ILTF) details

A1.1 – TERMS OF REFERENCE

1. Advise the ISPO and ISSC, via the international project engineer, on industry interaction aspects of the international SKA project, including:

- The effects of industry collaboration on the SKA project in its various phases, and principles for maximizing the number of positive outcomes;
- Political implications of industry collaboration, including the role of such collaboration in presenting the project to potential funding bodies;
- Opportunities for engagement of industry with the SKA project in its various phases, and identification of industry sectors, or individual players, likely to be interested in the international project;
- International legal and associated issues arising from industry linkages, and mechanisms for ensuring desired collaboration models remain possible throughout the project;
- Project management arrangements required to implement and oversee quality industry collaborations; and
- The effect on overall SKA project structure flowing from various alternative industry participation models.

2. Function as an impartial advice, commentary and review body for national demonstrator and pathfinder projects in areas such as those listed above.

3. Act as a forum for the exchange of ideas between the SKA project and industry.

4. Produce a whitepaper dealing with SKA industry interaction for consideration by the SKA community and by external assessors charged with evaluating the SKA project. The draft whitepaper will be available by December 31 2005, with the final version completed by March 31 2006. The whitepaper will be prepared according to agreed EWG guidelines (also applicable to other, more technical, papers) and will address issues such as those mentioned above.

A1.2 – ILTF MEMBERSHIP

David DeBoer, SETI Institute, USA
Peter Dewdney, NRC, Canada
Bernie Fanaroff, Fanaroff Associates, South Africa
Peter Hall (Chair), International SKA Project Office
Stephen Kahn, Pro Conta b.v., The Netherlands
John O'Sullivan, CSIRO ATNF, Australia
Richard Schilizzi, International SKA Project Office
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