The International SKA Project: Industry Interactions

Paper 1 – Background, and Collaborative Research and Development

SKA Memo 52

Peter J Hall

2 August, 2004

1. Introduction

The scale of the SKA project means that, as in other large science endeavours, interaction with industry is both inevitable and important. Traditionally, large radio telescopes have been built by combining the design and small-scale manufacturing skills of specialist astro-technology groups with the expertise of civil and infrastructure engineering consultants, the latter sometimes being responsible for construction project management and sub-contractor interactions. In the case of the SKA, this model of a rather late-stage industry link – operational in final design, construction and commissioning – is inadequate, principally because the high complexity and aggressive timescale of the SKA project demands even development resources which are beyond those available in radio astronomy groups.

I use the term "industry" to mean commercial enterprises other than the core SKA research and development groups maintained by participating scientific institutions. This first paper sets out some thoughts on industry interaction in general and explores in some detail the question of collaborative research links: an issue now facing several SKA consortia. After the establishment of a formal industry consultation and liaison group (Section 6), a second paper will examine wider industry interactions, including the framing of construction projects for both the SKA and any preceding international demonstrator.

2. The Nature of Industry Involvement

It is almost stating the obvious to say that the specialized groups within the SKA community are best used to address key design and prototyping challenges. Beyond these areas, there are many other fields in which "outsourcing" the challenges will be necessary and desirable. As in previous large radio telescope projects such areas might include:

- Site preparation and access provision;
- Structural (including reflector antenna) design, fabrication and erection;
- Infrastructure provision (buildings, power, communications, general services); and
- Legal and contract services.

It is probable that the SKA project office will retain one or more specialist management companies, possibly large consulting engineering practices with a range of in-house skills, to co-ordinate areas like those listed and to be responsible for the project delivery.

The large scale and wide geographical distribution of the SKA mean that the project will require at least construction and commissioning expertise not present in the astronomy community. It is sobering to reflect that, if the SKA construction period is nominally three years, the project demands the completion and commissioning of a 100 m (equivalent) telescope every 3-4 days! While naïve in the extreme, this calculation illustrates the need for the astronomy community to use great leverage, via industry, to actually build the SKA on any reasonable timescale.

How else is the SKA different from previous telescopes? The SKA will certainly need to build on the experiences of projects such as the VLA, ATCA, VLBA, GMRT, ALMA, EVLA, e-MERLIN and eEVN. However, the SKA's principle challenge – that of reducing the specific cost of collecting area by an order-of-magnitude – requires closer alignment with industry models geared for delivery of low unit-cost components and systems. For example, it is already clear that there are lessons to be learned in areas such as:

- Low-cost antenna fabrication (from manufacturers accustomed to stamping metal for applications such as automotive bodies);
- Low-cost, un-cooled, integrated receivers (from manufacturers of wireless networking, cell phone and similar consumer RF systems);
- High-bandwidth fibre optic communications systems (from telecommunications vendors and their carrier clients);
- Application of leading-edge computer and software engineering, including distributed computer solutions, to SKA data processing, storage and retrieval; and
- Infrastructure development in remote locations (including reliable, cheap, energy systems).

The SKA project cannot hope to build its own development teams in all such areas, nor to pay contract R&D rates for what may be, in some cases, speculative projects.

The most feasible way of harnessing both industry and astronomy expertise is to forge R&D collaborations between small specialist groups (e.g. within national SKA consortia) and motivated external parties. This then leads to a model in which industry is involved in developing enabling technology and techniques for the SKA via shared-risk or similar activities. Partners in such joint ventures will, of course, expect returns, usually via immediate or deferred financial paybacks, or via generation of intellectual property (IP) able to be applied for gain in other spheres.

There are several challenges in making the partnership model work well, including:

- Optimizing the level of industry involvement at various phases of the SKA project (project control and efficient resource use are major issues);
- Finding the manpower within national SKA groups to initiate and manage quality collaborations;
- Coordinating the various national collaborative endeavours within the international SKA project;
- Keeping the SKA priorities to the fore whilst managing the legitimate expectations of industry partners; and
- Managing the IP challenges flowing from joint R&D programs.

Greater reliance on the commercial sector, including the use of industry-oriented models for technology development and manufacturing will most likely modify the SKA project's risk assessment and management approach relative to even large predecessors, such as ALMA. This may lead to yet another area of collaboration, at least at the ISPO level, since the SKA process for handling risk will undoubtedly need to include many lessons learned from manufacturing and other industry.

With the commencement of demonstrator projects several SKA consortia are faced with the prospect of working closely with external R&D partners, an experience likely to build or reinforce critical skills (e.g. formal project management) in some groups. Before looking at points to consider in establishing collaborations, it is worth reflecting on what joint projects offer from both the industry and SKA viewpoints.

3. Collaboration from the Industry Perspective

A few collaborations between SKA groups and external collaborators already exist. Some of the already-cited benefits to industry from joint work include:

- The opportunity to grow and hone the creative energies of the best professionals in an imaginative project whose aim is no less than to chart the history of the Universe;
- The ability to perfect leading-edge techniques and products in a very demanding application, and to interact with highly 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 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.

Partners will have individual motivations for undertaking joint R&D with the SKA project, ranging from the development of their “human capital” to short-term tax write-offs in some countries. However, at this early stage of the project, many collaborators and enquirers are forward thinking individuals or corporations, deserving special consideration to optimize their (potentially) long-term association with the SKA.

4. Collaboration from the SKA Viewpoint

From the perspective of SKA scientists and engineers, some benefits of early industry links include:

- The opportunity to obtain alternative viewpoints on the design and implementation of low-cost components and systems;
- The ability to call on specialist development and manufacturing teams during prototyping activities;
- The opportunity to learn first-hand, via relatively small-scale projects, the merits and pitfalls of working with external groups;
- The identification of enterprises able to deal with scale and complexity, and to build SKA know-how in companies likely to be bidders in SKA construction work packages; and

- The possibility of identifying project management and similar enterprises able to contribute to objective decision making processes, and to risk assessment and management within the international SKA project.

There are common revelations which come when collaboration is first attempted. For example, the need for formalized planning and review may be unfamiliar in some astro-technology circles, as is the need to frame and manage interactions with professionals of quite varied backgrounds. PhD-level engineers accustomed to working in specialized groups often discover the challenges of achieving good outcomes from larger groups composed of individuals with varying skills and abilities.

In a sense, the SKA's technical paradigm shift away from highly specialist technology will need to be mirrored in a management shift away from reliance on heroes. Such a shift is one of degree of course: the SKA will certainly attract and retain some of the best people. The complexity and scale of the project is such, though, that a formalism for working with a much wider group cannot be avoided. Early industry links are a way of easing the transition to this project model.

5. Lessons from Other Research Collaborations

I can find no examples of R&D collaboration which match exactly the likely SKA partnership models. In particular, IP protection and utilization in other endeavours often differ greatly from models likely to be used in SKA projects. Nevertheless, there are relevant lessons from many projects and organizations. For example, CERN in Europe has a well-defined Technology Transfer Service (TTS), part of which is based on collaborative R&D. Fig. 1 shows their model for technology transfer and, while useful, the model supposes a dominant IP path which is mainly outwards from a large High Energy Physics (HEP) community. The CERN model is fairly typical of the management of commercialization by large R&D organizations around the world. Like many nations and blocs, the European Union also maintains incentive programs promoting multi-way R&D collaboration; many such programs have the aim of creating wealth through innovation and it would be useful for the SKA community to seek out, and record, any notable successes from these government-sponsored schemes.

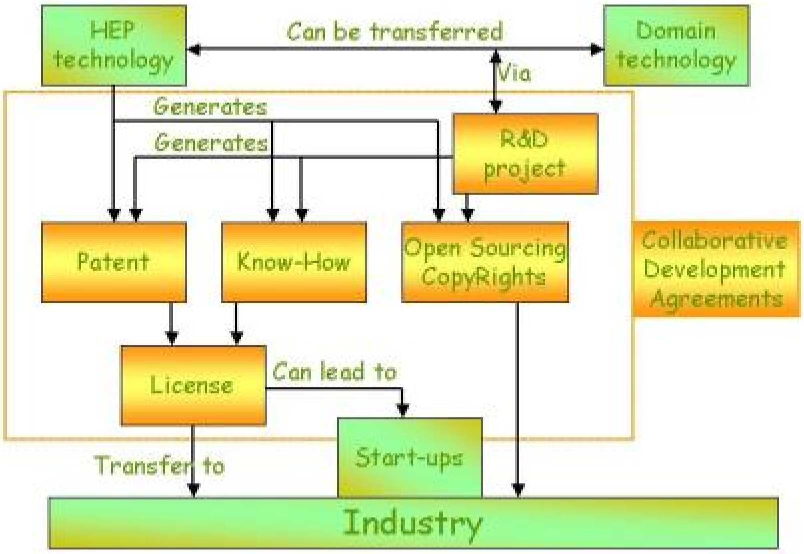

Fig. 1 – Mechanism in use by CERN for transferring IP from the High Energy Physics (HEP) domain to industry; note the use of collaborative R&D as a possibility.

Looking at a particular example of multi-arm R&D collaboration, a venture relevant to the SKA is NASA's project AGATE, a US undertaking which ran from 1994 – 2001 and formed what was said to be a unique (for the US) partnership involving 70 industry, university and government agencies. In general terms, the Advanced General Aviation Transport Experiment had aims involving the re-vitalization of the US general aviation industry via a focus on technology development. Interestingly for the SKA, a large fraction of the USD 300M program was concerned specifically with the reduction of advanced technology costs, allowing hitherto esoteric systems to be installed in relatively small aircraft. The program was divided into five major work packages and was operated by a consortium of 30 cost-sharing partners and 40 associate partners.

While the AGATE technological and commercial outcomes are significant (Gale, 2002), the lessons flowing from the consortium's collaborative ventures are more relevant to the SKA. Incidentally, AGATE was also interesting from a US perspective in that it underlined that pre-competitive R&D, and R&D with government input at that, is possible without the threat of invocation of anti-trust laws.

Holmes (1996) summarizes some of the lessons learned from AGATE and similar ventures. Many of these will be familiar to evaluators of other projects although, to pursue the SKA analogy, I have found it useful to retain three of Holmes' categories: criteria for collaboration entry, alliance design and implementation, and alliance lessons learned. Table 1 summarizes Holmes' questions related to establishment of collaborations. These are questions which research leaders in SKA consortia might address before framing and entering joint projects.

Table 1 – Collaboration Entry Criteria

	Question	**Comment**
1	Is the vision beyond the charter or business scope of any one or two of the partners?	If yes, diverse collaboration is likely desirable. If no, simple contracts may be better.
2	Does sufficient common ground exist in partners' business plans to collaborate on pre-competitive objectives?	If no, there is no basis for proceeding with a collaboration.
3	Do the industry partners have a primary stake in the collaboration?	If no, a simple contract may be better.
4	Do the partners share common levels of risk tolerance and learning capacity for new technology development?	If yes, there is a sufficiently level playing field. If no, it may be possible to level the playing field between participants in order for teaming to be successful (e.g. by establishing categories of consortium member).
5	Do the partners share a common sense of urgency in the result?	If no, important "glue" to hold the partnership together is missing.
6	Do the partners share sufficiently homogeneous business and personal interests to work together towards the vision?	If yes, a key "glue" ingredient is present. If no, the energy required to bind the consortium may be too great.

Question 6 (above) is an especially interesting one. In project AGATE the homogeneous vision was forged by establishing common interest groups based on systems. Furthermore, it was felt by participants that the unspoken, and high-minded, "brotherhood and sisterhood of aviation" was an important factor in the project's success. It is of course straightforward to transfer these observations to a science project like the SKA.

Holmes also mentions some guidelines for planning and managing alliances; these are summarized in Table 2.

Table 2 - Alliance Design and Implementation

	Guideline	Comment
1	Establish commitment by partners to shared vision and goals.	Engage individuals with authority to commit their organization; these people will typically be senior managers.
2	Negotiate specific objectives.	Establish partners' expectations in terms of e.g. risk, time, payoff and resource commitment.
3	Negotiate specific tasks, resources and organizational mandate.	Define tasks within the consortium and establish resources in partner organizations.
4	Sign agreements and establish governance.	Negotiate and finalize IP rights, and execute partnership legal documents committing partners to agreed resourcing. Consortium then establishes representatives to governing body (e.g. by election).

Finally, Holmes lists some lessons learned from AGATE and other alliances. Table 3 is a summary of those most relevant to the SKA. The consortia referred to would initially be national SKA bodies involved in collaborative R&D. However, as the SKA project grows, the same principles might be applied to activities managed by the International SKA Consortium.

Table 3 – Lessons from Alliances

	Lesson	Comment
1	Establish a compelling vision.	The bolder the vision, and the stronger the "threats" from consortium competitors, the stronger the consortium ties. (Survival is a compelling vision).
2	Every alliance is unique.	Every collaboration will have a unique mix of motivations, products, timescales, IP concerns, leadership candidates, funding sources and, perhaps, organizational structures.
3	Incorporate life-cycle planning.	Frame the collaboration to cope with all phases in a technology development effort.
4	Balance the portfolio.	The consortium must provide both near- and far-term returns.
5	Use a facilitator.	Engage an independent third party to develop the business side of each collaboration.

6	Implement sound system assurance processes.	System assurance supports the program office in the management of technical requirements documents, the master schedule, and speciality studies required by technical teams.
7	Communicate.	Plan communications with consortium members and with the wider community as though the life of the consortium depends on it – because it does.
8	Train.	Expect to have to train consortium participants in group processes and to undertake team building.
9	Expect resistance.	Alliances mean trading traditional control for more valuable influence. Not everyone is comfortable with this.
10	Anticipate culture shock.	Integrated teams often need broad expertise and the level of effort in a joint venture is often greater than R&D professionals have experienced. Participation in a joint venture requires personal commitments.
11	Organize for change.	Participating organizations need to establish a clear collaborative structure, and to identify sponsors, champions and change agents.
12	Manage outside in.	In collaborations, much greater attention to partners is needed than in simple contracted R&D relationships.
13	Segregate the change organization.	Protect champions and change agents from line management pressures in participating organizations.
14	Clarify career paths.	An individual’s participation in an alliance may be outside career paths within participating organizations; this needs to be recognized and accounted for.
15	Avoid mixing old and new business practices.	Resist the urge to take short-cuts and try to operate all functions in the joint venture as complete partnerships.
16	Streamline overseeing management.	Avoid inventing external overseeing functions if such functions are built into the alliance itself (ad hoc and formal advisory groups are useful review tools).

17	Anticipate operational support requirements.	Collaborations require support for meeting planning and operations, communications, legal consulting, asset management (for physical and intellectual property), documentation control etc.
18	Celebrate progress.	Establish a means of recognition of alliance progress. Press releases, newsletters, awards, and recognition are important to individuals and projects.
19	Prepare for technology transfer.	Expect a leakage of consortium personnel to joint ventures and new alliances.

5. Opportunities and Caveats in Industry Collaboration

The SKA project plan contains a number of key dates, each of which is relevant to commercial entities interested in the project. A list of dates and potential opportunities in various project phases is set out in Table 4.

At present, R&D collaborations with national groups, of the types mentioned in Section 4, are the most likely mechanisms for industry contact. Table 5 is a summary, for reference purposes, of the current interests of various SKA groups; it gives an indication of fields where collaboration is most likely. An important caveat when dealing with external parties is to stress that the SKA project is committed to high quality collaborations producing mutually valuable outcomes. The capacity of some research groups to manage external links is limited and, to ensure quality is maintained, corresponding limits on the number, or scale, of partnerships may therefore be in place.

Table 4 – SKA Key Dates and Associated Industry Opportunities

Year	Milestone	Notes
2003	Initial siting proposals received from four countries	Scope for continuing industry involvement in national site characterization
2004	Plans for national SKA demonstrators submitted	Possible industry links to national SKA technology development programs
2005	Final SKA site submissions	Possible industry involvement in compiling visible national proposals
2006	Choice of SKA site Critical review of technology demonstrator programs	Possible links in development of objective international methodology for site and technology selection, and risk management
2008	Choice of SKA technology	
2008	Construction of on-site SKA demonstrator (5% SKA area)	Likely industry participation in infrastructure provision, and instrument design and construction
2012	Construction of SKA	Maximum industry involvement at levels of final design, project management, and construction contracts and sub-contracts
2015	Stage 1 SKA complete and operational	Industry opportunities in commissioning, operations and maintenance
2020	SKA complete	Continuing operations and maintenance role for industry

The need to manage actively is perhaps the single most important lesson from the few joint SKA projects undertaken so far. Industry associates often interpret "collaboration" to mean something quite different to the mode envisaged by astronomers and academics. Typically, the industry partner will demand a more intense engagement, if only from the requirement to schedule groups and individuals effectively. To meet this demand, the joint project will often require the majority of a senior SKA consortium manager's time, in addition to solid blocks of time from those involved in bench-level work. Sound, long-term, business associations are, by academic standards, high-maintenance relationships. Such links should therefore only be considered for core, or mainstream, SKA activities, lest they hinder rather than help key development work.

The issue of legal framework arises early when collaborations are being planned. As in all relationships, harmonious and productive initial experiences will build trust, eventually streamlining the drafting of any required comprehensive legal agreements. In the early stages though, the level of risk exposure is usually small in practical terms, despite what lawyers will often maintain. Rather than sinking a promising project with legal weight, a good approach is often to draft a memorandum-of-understanding (MOU) setting out over-arching visions and agreement principles, then follow this with simple schedules (or annexes) relating to particular activities and deliverables. This simplified mechanism does not, of course, mitigate the need to outline clearly what the collaboration is meant to achieve (including deliverables) and what the timescales are.

These days the MOU or schedules will need to include clauses covering issues such as use and disclosure of jointly developed IP, liability limitation, governing jurisdiction, dispute resolution, and agreement termination mechanisms. However, by scoping the project appropriately, and employing a light legal touch, MOUs allow the all-important initial collaboration to proceed with minimum risk to the parties involved. Later, if the participants wish to build on the MOU with, say, a comprehensive commercial utilization agreement, the climate for doing so will be much better. Despite the attention given to framing legal agreements, many anecdotal reports from commercial authors support the contention that unsuccessful alliances usually fail because operational managers do not make them work, not because the contracts were badly written.

A question which often arises in industry dealings is whether early involvement with the SKA will lead to favourable positioning in terms of future contract allocation. It is certain that, notwithstanding the goodwill within the SKA Consortium, the final allocation of work packages will be a rather complex process, with considerations of technical expertise and fair return being paramount. Almost certainly, selection of major providers will be preceded by a bidding process, and familiarity with the SKA will confer advantages in that process. Nevertheless, with the lead time of the project and the uncertainties of international funding and associated politics, a better way of satisfying the reasonable expectations of collaborators might be to frame the sequence of activities such that first returns flow on a timescale of months or years, rather than of a decade or more.

Shorter-term milestones also have the advantage of helping to prevent the collaboration foundering due to the “commitment crisis” common in long-term projects (Lynch, 1989). This problem typically arises when one or more partners have other opportunities which compete for time, money, personnel and attention.

Table 5 – Interest, and Currently-Active R&D Areas, in SKA National Consortia
(Red = interest; green = active project)

R & D or Interest Area	**Aust**		**Canada**		**China**		**Europe**		**India**		**South Africa**		**USA**	
Site studies and infrastructure engineering	🔴	🟢			🔴	🟢					🔴	🟢	🔴	🟢
SKA scheduling, operations and maintenance models	🔴		🔴		🔴		🔴						🔴	
Outreach and public education	🔴	🟢	🔴		🔴	🟢	🔴	🟢	🔴		🔴	🟢	🔴	🟢
Low-cost manufacturing of small to medium diameter dishes					🔴				🔴	🟢			🔴	🟢
Low-cost, low-loss, artificial dielectrics for radio lenses	🔴	🟢												
Active surface adjustment techniques for very large (> 100m) reflectors			🔴	🟢	🔴	🟢								
Advanced mechatronic systems for feed positioning and antenna control	🔴		🔴	🟢	🔴	🟢			🔴				🔴	
Decade bandwidth single feeds for dish and lens flux concentrators	🔴	🟢							🔴				🔴	🟢
Broadband, active, phased arrays for aperture and focal plane applications	🔴	🟢	🔴	🟢	🔴	🟢	🔴	🟢			🔴			
Low-noise, highly integrated, receivers for both cryogenic and uncooled applications	🔴	🟢	🔴		🔴	🟢	🔴	🟢	🔴		🔴		🔴	🟢
High-speed (Tb/s) digital fibre optic links for distance regimes extending from 100 m to 3000 km	🔴	🟢	🔴		🔴	🟢	🔴	🟢	🔴		🔴		🔴	🟢
Low-cost, high-speed (Gs/s) analog to digital converters	🔴	🟢	🔴		🔴	🟢	🔴	🟢	🔴		🔴		🔴	🟢
High-speed digital signal processing engines (Pb/s) and ultra-fast supercomputing	🔴	🟢	🔴	🟢			🔴	🟢			🔴		🔴	🟢

Software engineering for robust, intelligent, array control and data processing	🔴				🔴		🔴	🟢	🔴				🔴	🟢
Radio-frequency interference mitigation using coherent and incoherent techniques	🔴	🟢			🔴		🔴	🟢					🔴	🟢
High dynamic range (>60 dB) image formation using sparsely-sampled Fourier plane data	🔴	🟢	🔴		🔴		🔴	🟢	🔴				🔴	🟢

6. Managing SKA R&D Collaboration

There are several reasons for internationally coordinating SKA industry interaction, including:

- The need to establish what collaborative projects are already in place;
- The desirability of applying available R&D manpower evenly across key project needs;
- The importance of raising the profile of the SKA project in professional engineering and trade forums;
- The requirement to present a coherent, professional, message to increasingly globalized enterprises;
- The necessity to give authoritative, uniform, advice on major project issues, such as IP protection and utilization, possible legal frameworks for alliances, and potential long-term returns to partners;
- The need to demonstrate to government and related agencies that the project is intent on finding ways of transferring technology advances beyond the astronomy arena; and
- The imperative to share information and experiences between SKA consortia, and to begin building a common project expertise in dealing with industry partners.

On the other hand, there are many local differences in the way that R&D collaborations are implemented and managed.

One way of addressing simultaneously the challenges of international and national management is to implement a structure such as the one proposed in the latest SKA Management Plan (Schilizzi, 2004). In this model, industry R&D would be coordinated via an Industrial Liaison Committee (ILC), chaired by the International Project Engineer. Whilst most joint projects would actually be managed by the consortia research leaders sitting on the ILC, the Committee itself would have important additional roles in building links with industry, and with facilitating collaboration between industry, national SKA consortia and, where appropriate, the ISPO.

As well as SKA research leaders, the ILC would also have representatives from industry, preferably individuals with extensive experience but few pecuniary links with the project. As far as possible, these representatives should be, or have been, associated with global businesses; they would be invited on the basis of their professional and commercial expertise, with national affiliation being a secondary factor. The ILC might meet annually, in rolling locations, with each meeting coinciding with an SKA industry forum or workshop.

7. Conclusion

Building the SKA will be an immense undertaking. Industry involvement will be critical throughout the project and early collaborative R&D projects provide essential development resources while, at the same time, providing an experience base for future, much more extensive, industry interaction.

References

Gale, K., AGATE alliance commercialization impact report, NASA-WP#12.0-120011-114-Report, 2002 (rev. 4).

Holmes, B. J., (Re)inventing government-industry R&D collaboration, NASA TM-110271, 1996.

Lynch, R. P., The practical guide to joint ventures and corporate alliances, Wiley, 1989.

Schilizzi, R. T., Draft White Paper – Implementation of the SKA Management Plan, June 2004.