

ENABLING TRANSFORMATIONAL SCIENCE THROUGH GLOBAL COLLABORATION AND INNOVATION USING THE SCALED AGILE FRAMEWORK

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Abstract

The Square Kilometre Array Observatory (SKAO) is one observatory, with two telescopes on three continents. It will be the world's largest radio telescope once constructed and will be able to observe the sky with unprecedented sensitivity and resolution. The SKAO software and computing systems will largely be responsible for orchestrating the observatory and associated telescopes, and processing the science data, before data products are distributed to regional science centres. The Scaled Agile Framework is being leveraged to coordinate forty lean agile development teams that are distributed throughout the world. In this paper, we report on our experience in using the Scaled Agile Framework, the successes we have enjoyed, as well as the impediments and challenges that have stood in our way.

SKA OBSERVATORY

SKAO is an intergovernmental organisation (IGO) with 16 countries engaged in a partnership to design, build and operate the next-generation radio astronomy observatory. SKAO consists of a global headquarters located in the UK, a mid-frequency radio telescope (MID) and a low-frequency radio telescope (LOW). The MID telescope [1] is being constructed in the Karoo region of South Africa, and will consist of 197 dish antennas, while the LOW telescope [2] is being constructed in Western Australia and will consist of 131,072 log periodic antennas.

Both telescopes will use interferometry and a technique called aperture synthesis to combine signals from each antenna in a Central Signal Processor, located in Cape Town and Perth respectively. A Science Data Processor will leverage a supercomputer in each of these locations to ingest high-bandwidth data from the Central Signal Processor to produce data products, calibration solutions, and science alerts. Data products are delivered to SKA regional data centres scattered around the world for scientific analysis. Each telescope is orchestrated by a Telescope Monitoring and Control subsystem that provides configuration, observation execution, alarm handling, and monitoring services. An Observatory Science Operations subsystem provides proposal management and execution functions.

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As such, the telescopes are in many respects “software telescopes” requiring a range of developer skills, including:

- Platform Developers.
- Database Developers.
- Monitor and Control Developers.
- User Experience Developers.
- Radio Astronomy Data Scientists.
- High Performance Analysis Algorithm Developers.
- High Performance Computing Engineers.

Given the magnitude of the challenge, the range of skill requirements, and diverse membership of the observatory, it was anticipated that hundreds of developers spanning multiple geographic locations would need to collaborate to develop the software aspects of the observatory.

FRAMEWORK DECISION

Waterfall approaches in similar projects had a bad track record, and so a large-scale lean-agile methodology and framework was favoured.

Key software and computing stakeholders had already bought into the basic agile principles [3]:

- Continuous delivery of valuable systems.
- Working systems as the primary measure of progress.
- Built-in quality and attention to technical excellence.
- Continuous improvements and plan-do-check-adjust cycles.
- Synchronised cadence with increments and iterations.
- Engaging with key stakeholders all the way.
- Leveraging motivated individuals that are enabled with decentralised decision making and autonomy.

SKAO considered five lean-agile frameworks: Disciplined Agile Delivery (DAD), Dynamic Systems Development Method (DSDM), Large Scale Scrum (LESS), Modular Framework for Scaling Scrum and the Scaled Agile Framework [4].

SKAO chose to implement the Scaled Agile Framework because of its large community of practitioners, the quality of its documentation and training material, and its support for developing cyber-physical systems.

IMPLEMENTATION ROADMAP

The Scaled Agile Framework is promoted as being a knowledge base of principles, practices and competencies for achieving agility by implementing Lean, Agile and DevOps at scale. Importantly it also provides a common language, a set of roles and responsibilities, a structure (teams, trains, solutions) to organise around value delivery and an implementation roadmap to get started.

Change Agents

SKAO embraced the implementation roadmap and started training change agents in July 2018. All but three of the pictured change agents in Fig. 1 are still working on the SKA project to-date and have made immense contributions to the project. With hindsight, it seems like the right change agents were identified to lead the implementation. This has been a critical success factor.

The SKAO leadership team received “Leading SAFe” training in Sep 2018. It’s important that the leadership team embrace the same mindset and principles. Critically, the framework was deemed by the leadership as something to be implemented within the software and computing ecosystem, but not appropriate for other parts of the project like infrastructure (buildings, roads, power etc), dish and antenna construction, and assembly integration and verification teams. More traditional approaches would be followed in these areas. The observatory ultimately requires that all systems integrate to operate effectively, and hence needed to find a way to integrate the different approaches too. Tensions currently arise in the interface between approaches given that they follow different contracting models, use a different lexicon, and ultimately have proponents that remain sceptical of the other approach.

Organising Around Value

The framework advocates performing a Value Stream and ART Identification Workshop ahead of launching a team of teams known as an Agile Release Train. An operational value stream in the parlance of the framework is a sequence of activities and the people needed to deliver a product or service to a customer, while a development value stream contains the activities and people that produce the solutions used by an operational value stream.

Although some consideration was given to this topic, this step was largely omitted in the SKAO implementation. Considerable time had already been spent during the SKAO design phase [5] to understand the operational value stream for the SKAO but given that the construction phase had not yet started at this time, organisations were offering teams to commence development activities on a goodwill basis in anticipation of receiving a formal contract. SKAO could therefore not dictate who should participate, and how the development teams should organise themselves. SKAO was simply happy to get started.

Train Everyone

Agile team members received “SAFe for Teams” training immediately prior to the launch of the first increment. Large parts of the developer community had already been exposed to agile methods; however, they had not necessarily scaled beyond a few teams in their experience. As a result, the mindset and principles were readily embraced, however certain aspects of the framework were seen as additional overhead. A team does not experience the framework in the same way that other roles potentially straddling multiple teams, or teams of teams does. This leads to differing opinions in terms of the usefulness of certain constructs within the framework.

SKAO has continued to offer role-based training every quarter since the launch event. The change agents have spear headed the training efforts. The vast majority of team members have received Scrum Master, Product Owner or Teams training to date. This helps to ensure that the common lexicon is understood across the breadth and depth of the framework implementation and that the change agents remain engaged with the latest developments in the framework.

Launch an Agile Release Train

The first team of teams, known as an Agile Release Train, was launched in Dec 2018, consisting of five agile teams and ~40 people. The initial teams were largely focused on developing complex subsystems, and in some cases were aligned to organisational structures. This was not ideal, as they should have been organised around value delivery. The launch took place at an all-hands face-to-face planning event hosted at Jodrell Bank (UK), with some team members participating remotely.

Negative feedback obtained during the first planning event retrospective included:

- Need better defined features and should be available earlier.
- Poor experience for remote participants (not seeing white boards, not knowing who is speaking all the time, missing out on side conversations).
- Exhausting timings, particularly for remote participants located in India with a 5:30 time zone difference.

Positive feedback from the retrospective included:

- Transparent and inclusive process.
- Loved the sense of focus and commitment.
- Face-to-face event provided a chance to interact with other teams.
- Loved the demos, and additional context and vision.
- Involvement in decision making.

Overall, the launch was a success with several improvements identified for the next quarterly planning event. The plan-do-check-adjust approach had delivered its first round of feedback.



Figure 1: Change agents attending the inaugural SAFE™ Program Consultants (SPC) training at Jodrell Bank in 2018.

Launch More Agile Release Trains

Exactly one year after the launch, the SKAO implementation of the framework had scaled to 14 teams across two Agile Release Trains. It would have been impossible to scale this quickly without the framework providing the lexicon, the roles and responsibilities, the hierarchy, and principles and practices.

Following another face-to-face planning event hosted at Jodrell Bank (UK), the feedback boards included the following entries:

- Features too big and should be socialised earlier.
- Meetings too early for some, and just right for others in New Zealand!
- Poor audio for remote participants, camera not able to zoom-in on details.
- Good communication at the face-to-face event

The scaling incorporated more teams across more time zones. Now the range included New Zealand all the way to Canada with the United Kingdom and other European countries in the middle. Remote participants were bearing the brunt of the time zone differences while others were attending a face-to-face planning event.

COVID struck relatively early in 2020 and ended all face-to-face planning events. This was a change driver, resulting in the adoption of more collaborative tools such as Slack for interactive chatting, and Miro for whiteboarding. It levelled the playing field in that everyone needed to interact remotely. Figure 2 shows a pre-COVID physical planning board, while Fig. 3 shows a virtual planning board

leveraging the MIRO whiteboarding tool integrated with the Jira issue tracking tool.

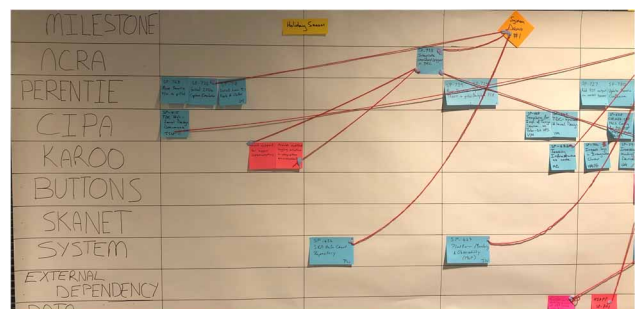


Figure 2: A populated planning board, showing Features (blue stickies) and dependencies (red string), Dec 2019.

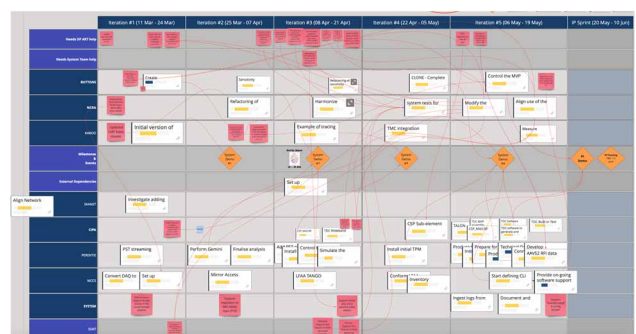


Figure 3: A populated planning board, showing Features (white cards) and dependencies (red stickies and lines), Mar 2020.

SUCCESSSES

Scaling

Scaling is hard because inefficiencies compound. Scaling requires that the demand for resourcing increases at a slower rate than the growth itself. Otherwise, one is simply growing. Sustainability issues start manifesting themselves when there is growth instead of scaling.

SKAO deployed a minimal implementation of the framework, referred to as the Essential Configuration, to deliver systems in the first year following the launch. Soon after the introduction of the second Agile Release Train, SKAO started appointing a Solution Team to steer and coordinate additional Agile Release Trains with respect to content, technical and process domains.

The Solution Team migrated the implementation from the Essential Configuration to the Large Solution Configuration. This essentially introduces several synchronisation points that span multiple Agile Release Trains. It introduces the concept of a Solution Intent, a shared and curated repository of intended and emergent requirements, design and tests defining the present and future software. Roadmapping is also abstracted to show a set of goals to be achieved over multiple planning horizons.

The framework provided guidance in terms of the essential processes and practices to deploy at the outset, and how to scale these to larger configurations. Role based training provided alignment to the processes and practices throughout the rollout. Scaling from five to forty teams would not have been possible without the framework.

SKAO does however experience sustainability issues in key areas, and so there is still room for improvement in its framework implementation. Sustainability issues tend to be felt more acutely higher up the hierarchy, where there is the need for greater accountability and where misdirected communication has its greatest impact.

Transparency and Trust

Transparency is one of the framework's core values given that it enables better decision making, based on accessible information rather than assumptions or speculation.

SKAO endorses this value and promotes open communications to make timely and transparent decisions in the best interests of the project. Some examples that exemplify this value include:

- Open system demonstrations every iteration to show progress towards objectives.
- Collaborative problem-solving workshops every quarter to perform root cause analysis on systemic problems.
- Product, progress and process related metrics published in near real time across the project.
- Open spaces/projects on all major collaboration platforms.
- Near real time publishing of survey results e.g., Happiness, Team and Technical Agility.

By leveraging more collaborative tooling, and by extending the duration of the planning events, remote participants across multiple time zones enjoy an improved experience.

Figure 3 shows a significant number of features on the planning board with numerous red lines denoting dependencies with other teams, and even with another Agile Release Train. Features had become smaller to enable a better flow of delivery throughout the increment, but in many cases dependencies still hampered their progress. This was a sign that the teams were not optimally organised around value delivery. SKAO had still not hosted a Value Stream and ART Identification workshop!

Several side effects became evident once SKAO migrated to smaller features. It became harder for stakeholders to understand the overall alignment (seeing the wood for the trees), program teams became overloaded in terms of maintaining oversight of all the features, and the autonomy of the teams was being undermined in that some teams felt like they were being micro-managed.

Fast forward to Oct 2023 and the SKAO implementation of the framework had scaled even more since launching in Dec 2018. See Table 1 for current sizing parameters.

Table 1: Software and Computing, Oct 2023

Parameter	Count
People	~300
Agile Teams	40
Agile Release Trains	4
Partner Organisations	40
Countries	15

Planning events continue to be hosted on a set cadence every quarter, largely leveraging a model known as “distributed colocation”. Distributed colocation entails having teams collocate in regional centres around the world, whilst the event is hosted virtually. This allows teams to enjoy the benefits of a face-to-face interaction, whilst minimising long distance travel and associated costs. This model also provides the opportunity for teams from different Agile Release Trains to collocate, providing a communication bridge across the Agile Release Trains.

SKAO is on the verge of launching another two Agile Release Trains in Dec 2023. The new MID and LOW trains will be aligned to the MID and LOW Telescope value streams, whilst the remaining Agile Release Trains deliver products and services common to both telescopes. It is anticipated that this arrangement will streamline communications, reduce dependencies across trains, improve sustainability issues and enable further growth as operational teams start to ramp up. In other words, improve value delivery. The MID and LOW trains will be led by the respective Telescope Delivery Teams and will drive integration activities across both software and computing products, including products delivered by more traditional approaches and contracts.

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Transparency allows trust to develop. SKAO performs a trust and compatibility survey within its supplier network once a year and has achieved outstanding results within this network since commencing the survey in 2022. Figure 4 shows the results of the 2023 survey across five dimensions that are indicative of a healthy trading partner relationship.

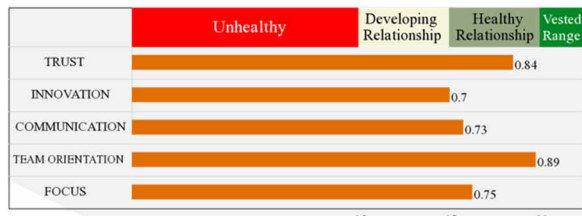


Figure 4: Overall results of the Trust and Compatibility survey conducted by an independent consultant within its Software and Computing supplier network during 2023.

SKAO’s developer community is largely provided on a contractual basis by a global supplier network. Suppliers enter an NEC4 relational contract with the SKAO based on the Vested approach [6]. A relational contract puts the supplier and client on a more equal footing, and is based on guiding principles of reciprocity, honesty, autonomy, equity, loyalty, and integrity. The relational contracting approach enables a relationship build on trust.

Relentless Improvements

Progress coupled with feedback can be more valuable than striving for illusive perfection from the outset. This only works if the feedback loop is closed at regular intervals, and one makes space for relentless improvement as part of the process.

SKAO has endorsed this framework core value, by building retrospectives into the process at various levels, and by promoting teams and teams of teams to set aside capacity each iteration and increment for indirect value objectives, including improvements.

Over and above hosting retrospectives and problem-solving workshops on a regular cadence, SKAO conducts a Happiness Survey every six months to gauge the health of the collaboration from a people perspective.

The survey asks team members to rate how they are feeling about their work, team and SKAO on a scale of 1-5 (rubbish to super happy). Additionally, SKAO developed a series of statements around intended behaviours with respect to their working relationship, including alignment, engagement, inclusion, respect, commitment, responsiveness, technical excellence and transparency. The intended behaviours are rated on the same 1-5 scale.

By reviewing the results by team and Agile Release Train and comparing over time, the project has gained valuable insights into the impact of changes and improvements on the project / participants and identified issues to tackle with urgency.

Figure 5 shows that all behaviours improved from planning increment PI14 to PI16, but that alignment remains an area of most concern. The improvement is due to the

launch of another Agile Release Train and resultant reorganisation of teams.

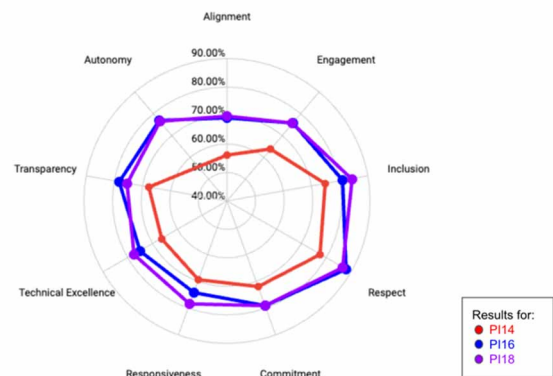


Figure 5: Aggregated results of the Happiness Survey with respect to the intended behaviours over 3 planning increments. 100% represents the case where all responses are given the highest rating, and 0% the lowest rating.

IMPEDIMENTS AND CHALLENGES

Alignment

Alignment comes in many forms such as aligning around roles and responsibilities, processes, goals, requirements and so on. Too much alignment, and one stifles the autonomy of the teams, possibly hampering creativity and innovation. Hence a balance is always needed.

SKAO predominantly looks to generate alignment via the quarterly all hands planning events. Planning events form the heartbeat of each Agile Release Train. Planning events act as a forcing function for the organisation to re-evaluate its priorities, the progress against the roadmap, and re-evaluate the most important things to focus on in the next quarter.

SKAO socialises a set of top-level *solution goals* and associated features (stakeholder needs) and enablers (architectural infrastructure) ahead of each quarterly planning event. Teams pull the work items while matching demand to capacity, establish team objectives, and back this up with an iteration-by-iteration plan. The team objectives are aggregated against the top-level goals, commitment is obtained, and the first iteration is kicked off.

The challenge with this approach is that the teams tend to align around the features and enablers that they have pulled and risk losing sight of the top-level goals. The features and enablers are in some cases relatively fine grained posing a risk that there is too much alignment at this level, and not enough alignment around the goals.

SKAO is planning to pivot the process ahead of the next planning event in Dec 2023. The plan is to:

- Introduce the concept of *system goals* for the MID and LOW Telescopes i.e. broader scope.
- Abstract the feature and enabler backlog items to a higher level, similar to the scale of the previous *solution goals*.

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- Facilitate brainstorming sessions to uncover key dependencies, collaborations, constraints, and limitations ahead of a planning event.
- Aggregate team objectives against the feature and enabler backlogs.

By abstracting the features and enablers to a higher level, SKAO is expected to focus alignment at the appropriate level again. Team level autonomy and delegation will be increased. Features and enablers are expected to become more relatable to key stakeholders. Cross team collaboration and coordination should be facilitated by the brainstorming discovery process allowing better plans to be formulated.

Communication

Communicating at scale is challenging. There are currently ~300 people in the Software and Computing ecosystem across 15 countries spanning Australia in the east to Canada in the west.

Communication issues have been raised as systemic problems in various retrospectives from time-to-time. A sample of the issues are listed below:

- Struggling to find relevant information within extensive knowledge bases.
- Engagement with the right people in the right meetings is lacking, specifically within the developer community.
- Confusion due to insufficient guidance.
- Multiple sources of truth (duplication).

SKAO has put considerable effort into improving communication to eliminate wasted effort. Some of the steps taken to address the challenge are:

- Establishing meeting guidelines and templates to ensure they are effective.
- Publishing shared calendars to avoid conflicts.
- Introducing asynchronous and hybrid meetings.
- Performing frequent retrospectives and implementing improvements.
- Performing regular content curation in collaboration tools such as Confluence.
- Managing distribution groups for email and chat purposes
- Synchronising information across tools i.e. integrating tools to avoid duplication
- Establishing glossaries and onboarding programs for new starters.

The Jira issue tracking tool has gained a lot of traction within the project due to its ease of use and flexibility (200 projects, ~1350 users, ~110,000 issues). Jira is the target for a number of tool integrations, to enable the presentation of information via dashboards, to facilitate reporting, and to enable data modelling (see Fig. 6).

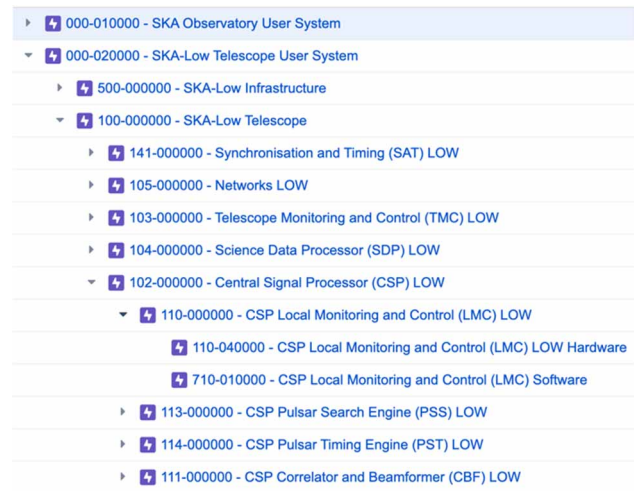


Figure 6: A subset of the Product Breakdown Structure modelled in Jira, based on data synchronised from a Configuration Management system (Alim).

Sustainability

The quarterly planning increment cadence acts as a forcing function. The previous increment needs to be closed out, while a new increment is prepared. Features and enablers are released, team objectives are assessed, new features and enablers are prepared, prioritisation workshops are hosted, systemic issues are analysed, innovation projects are implemented, and the planning events are concluded. There is a lot happening during framework’s “innovation and planning sprint”. This tends to create a “perfect storm” and is the key period during which sustainability issues are experienced.

If the continuous delivery pipeline is truly working, then theoretically there should not be a crunch at the end of the planning increment. Likewise, if the roadmap is mature, and the backlogs are healthy, then preparing for a new planning increment should theoretically not be too taxing.

SKAO’s implementation of the framework has not yet matured to the extent that the innovation and planning sprint is not something that takes an astonishing amount of effort to conclude.

CONCLUSION

Delivering the SKAO vision is an extraordinary challenge. Unlocking answers to the fundamental questions was never going to be easy. The original change agents responsible for the Scaled Agile Framework implementation are largely still committed to realising that vision five years after embarking on the journey. This is an indication of their trust in the framework.

The principles and values that underpin the Scaled Agile Framework are sound, the processes and practices however need to be customised to the project’s context as it evolves to meet the challenge. Learning from other practitioners with similar challenges presents an opportunity to fast-track solutions, and is the reason for sharing the SKAO experience, successes, challenges, and impediments.

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