Can Requirements Be Creative? Experiences with an Enhanced Air Space Management System

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Abstract

Requirements engineering is a creative process in which stakeholders work together to create ideas for new software systems that are eventually expressed as requirements. This paper reports a workshop that integrated creativity techniques with different types of use case and system context modeling to discover stakeholder requirements for EASM, a future air space management software system to enable the more effective, longer-term planning of UK and European airspace use. The workshop was successful in that it provided a range of outputs that were later assessed for their novelty and usefulness in the final specification of the EASM software. The paper describes the workshop structure, gives examples of outputs from it, and uses these results to answer 2 research questions about the utility of creativity techniques and workshops that had not been answered in previous research.

1. More Creative Requirements Processes

As we have reported previously [10,11,12], requirements engineering is a creative process in which stakeholders and engineers work together to create ideas for new software systems that are eventually expressed as requirements. The importance of creative system and product design is expected to increase over the next decade. Creativity is indispensable for more innovative product development [6], and requirements are the key abstraction that encapsulates the results of creative thinking about a system.

Most current requirements processes and research activities support problem analysis and system specification. In contrast, invention is often perceived as part of the design process that follows requirements engineering [7]. One assumption behind approaches such as *i** and KAOS and commercial processes such as the RUP is that stakeholders have sufficient knowledge to already know their requirements. However, this is increasingly flawed because of the breadth of expertise that is needed to specify complex systems and the need for stakeholders with different areas of expertise to work together to generate requirements.

One challenge is to build on previous successes [10,12] and integrate creativity techniques into mainstream requirements and software engineering processes. This paper reports results from one previously unreported creativity workshop within the RESCUE requirements process [11] that was run to discover new requirements for Enhanced Air Space Management (EASM), a new system for the more flexible use of airspace with the UK and Europe. EASM is, in essence, a scheduling system that will enable more effective, longer-term planning of UK airspace use. It comprises a new EASM software system, and changes to both related systems such as flight data processing, and the work of humans who will use the software.

The core EASM team of two systems engineers worked with air traffic management experts to determine the EASM requirements that would be expressed in an Operational Concept of Use (OCU) document – a high-level specification of the software system and redesigned work. The EASM team applied the first 2 stages of RESCUE. A single two-day creativity workshop took place 4 months into the EASM requirements process, once the initial scope and goals of EASM had been established.

As with previous projects, the uniqueness of the EASM workshop and project meant that controlled studies could not be used to investigate the effectiveness of the workshop. Instead we used qualitative data to explore research questions unanswered from investigations of previous workshops. In particular, for the first time, we sought data to explore whether ideas generated during the creativity workshop were creative and had a direct impact on the specification delivered at the end of the RESCUE process.

Section 2 of this paper describes RESCUE. Section 3 describes EASM's creativity workshop and the techniques implemented in it, and introduces the two research questions that we sought answers to. The fourth section reports the results and demonstrates them with EASM examples. Section 5 seeks to answer the two research questions using data gathered from the creativity workshop. The paper ends with lessons learned from the reported workshop.

2. RESCUE And Its Creativity Workshops

RESCUE is a concurrent engineering process in which different modeling and analysis processes take place in parallel [9]. The concurrent processes are structured into 4 streams. The two most important streams are:

- System goal modeling to model the future system boundaries, actor dependencies and most important system goals;
- Use case modeling and scenario-driven walkthroughs to communicate more effectively with stakeholders and acquire complete, precise and testable requirements.

Creativity workshops normally take place after a requirements team has specified the system boundaries and before it specifies use cases. Their main purpose is to discover and invent requirements and ideas needed to specify use cases. Inputs to the workshops include the system context model from the system goal modeling stream and use case diagrams from the use case modeling stream.

We designed RESCUE to separate the creativity workshops from other more practical requirements activities such as use case specification, requirements acquisition and requirements management. In the EASM project, the team undertook these other requirements activities before and after the workshop.

2.1 Previous Creativity Work

As we have reported previously [10,11], little requirements engineering research has addressed creative thinking directly. Brainstorming techniques and RAD/JAD workshops [4] make tangential reference to creative thinking. Most current brainstorming work refers back to Osborn's text [15] on principles and procedures of creative problem solving (CPS). The CPS method describes six stages of problem solving: mess finding, data finding, problem finding, idea finding, solution finding and acceptance finding. It was originally intended to help people understand and use their creative talent more effectively [8]. The six stages are arranged into three groups – understanding the problem, idea generation, and planning for action. A recent CPS manual [3] describes activities for supporting each model stage. Examples include *the matrix*, which involves making lists then selecting items from each list at random and combining them to generate new ideas, and *parallel worlds*, which uses analogical reasoning to generate new ideas. However, there are no reported applications of the CPS model to requirements processes.

In the requirements domain, Robertson [18] argues that requirements analysts need to be inventors to bring about the innovative change in a product that gives competitive advantage. Such requirements are often not properties that a stakeholder would ask for directly. Nguyen et al. [14] observed that teams restructured requirements models at critical points when they re-conceptualize and solve sub-problems, triggered by moments of sudden insight. Mich et al. [13] report the successful use of the elementary pragmatic model from communication theory in a controlled environment to trigger combinatorial creativity during requirements acquisition. However, none of these approaches exploit creativity theories or models directly, and there are few other references to creativity in mainstream requirements and software engineering. Requirements analysts lack processes to apply to guide their creative processes.

2.2 Creativity Workshops in RESCUE

RESCUE incorporates creativity workshops to encourage creative thinking with which to discover and invent requirements. The workshop activities are designed using 3 established models of creativity from cognitive and social psychology that we use for three purposes. Firstly, in order to encourage creative thinking, it is essential to define creativity and creative thinking. The models provide us with important definitions of creativity. Secondly, it is important to structure the workshops into different creative processes. The models provide us with important taxonomies of creative thinking with which to structure creative processes in workshops. Thirdly, one of the models provide procedural guidance for creative problem solving that we apply directly to each workshop's design.

In RESCUE we adopt Sternberg's [21] definition as prototypical of those available in the literature. Creativity is defined as "*the ability to produce work that is both novel (i.e. original, unexpected) and appropriate (i.e. useful, adaptive concerning task constraints)*". We designed the EASM workshop to produce requirements that were novel in the EASM domain, novel to the stakeholders involved in the EASM requirements process, and useful for the EASM system according to these stakeholders.

So how did we apply the 3 creativity models? Firstly, we designed the workshop to support the divergence from and convergence towards ideas as described in the CPS model [15]. The CPS model provided practitioners with techniques that encourage creative thinking. As such each workshop period, which typically lasted half a day, started from an agreed current system model, diverged, then converged towards a revised agreed model that incorporated new ideas at the end of the session. Secondly, we designed each workshop period to encourage one of 3 basic types of creativity identified by Boden [2] – exploratory, combinatorial and transformational creativity. These 3 types are based on computational creativity approaches that define a space, then explore and transform it. Thirdly, we designed each period to encourage 4 essential creative processes reported in [17]: preparation, incubation, illumination and verification. Poincare's philosophical model was based on personal reflections about his own scientific processes. We designed incubation and illumination activities using the type of creativity that we sought to encourage.

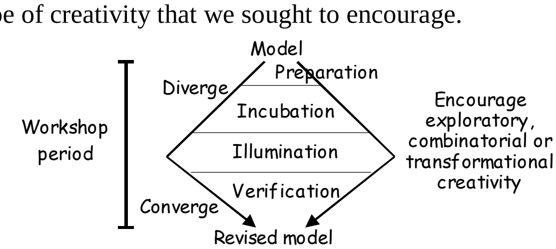


Figure 1. The basic structure of one creative period during a RESCUE creativity workshop

In RESCUE, we did not integrate these 3 creativity models directly in a single, consistent model of requirements creativity. Rather these models contributed separately to the design of the creative requirements processes at different levels of granularity. The CPS model processes provided a coarse-grain structure of repeating divergence from and convergence towards ideas during workshop periods. Poincare's model provided finer-grain processes – incubation and illumination – with which to achieve this divergence and convergence. Boden's types of creativity were used to select different creativity techniques for achieving incubation and illumination during convergence and divergence. Figure 1 depicts the processes and techniques proposed by the models in a creativity workshop. A two-day workshop is composed of 4 such half-day creativity periods. In each period we use a different creativity technique to encourage different types of creativity. For example, in one period we might use analogical reasoning to encourage exploratory creativity, or storyboarding to encourage combinatorial and transformational creativity.

Prior to the EASM workshop, the RESCUE team had facilitated 9 creativity workshops in the air traffic and policing domains to discover and document future system requirements and design ideas. Three successful one-day workshops had been held at Eurocontrol in 2001 to discover new requirements for CORA-2, a socio-technical system to support the resolution of conflicts between aircraft on collision courses [12]. In 2002, two half-day workshops were run with the UK's Police IT Organisation to discover new requirements and opportunities to exploit biometric technologies in policing [16]. In 2003, one two-day creativity workshop was run with Eurocontrol to discover new requirements and ideas for DMAN, the departure management system for major European airports such as Heathrow and Charles de Gaulle [10]. The workshop succeeded, in that it established requirements for DMAN integrated with structured models used in RESCUE. Three two-day workshops using this model were also ran to discover operational concepts and requirements for Eurocontrol's new Multi-Sector Planning (MSP) system [11].

However, in spite of these 9 previous workshops, project pressures and the absence of available resources meant that had been unable to explore the impact of creativity workshop ideas on the final requirements specifications or analyze the perceived novelty of the ideas. Therefore, in EASM, resource and time was put aside at the end of the project for key stakeholders to assess creativity workshop outputs and, through them, the effectiveness of the workshops themselves. This assessment and the report of a new workshop are the main contributions reported in this paper.

3. The EASM Creativity Workshop

Two facilitators, 2 scribes, 2 different external experts and 19 stakeholders attended the EASM workshop. Each stakeholder was an employee of Eurocontrol, a national air traffic service, military air traffic control, or a major airline.

The workshop was held in a large meeting room. The system context and use case models and use case précis (one unstructured paragraph describing the behaviour of actors in a use case) provided the structure for the workshop room itself. At the beginning of the workshop each model and précis was posted on separate $1m^2$ pin boards placed around the workshop room that became the physical and logical structure of ideas and requirements associated with that model and use case during the workshop.

The workshop was facilitated to encourage a fun atmosphere so that the stakeholders were relaxed to generate and voice ideas without fear of criticism. During creativity periods, standard RAD/JAD facilitation techniques and rules [1] such as avoiding criticism of other people's ideas and time-boxing each topic under discussion were applied.

Stakeholders were supplied with A6 RESCUE colour-coded idea cards, post-it notes, A3 paper, pens and blue-tack with which to record the results from each period. Everything captured on the pin boards was documented electronically in a workshop report sent to all stakeholders.

Inputs to the workshop included a system context diagram, use case diagram and use case précis for the EASM system developed by the 2 systems engineers based on early analyses and existing EASM documentation. On day-1, the morning period activities included system-wide and use case-specific brainstorming, constraint identification and removal followed by group brainstorming assuming the removal of selected constraints. After lunch stakeholders listened to an expert presentation on the design of museum exhibitions, then generated EASM ideas and requirements using analogical mappings between air space management and museum exhibition that the stakeholders reported back to the workshop at the end of the day. On day-2, in the morning period, the facilitators conducted a reflection session to review the first day activities. Stakeholders then listened to an expert presentation on TV programme scheduling as a basis for generating new EASM ideas about airspace management using analogical mappings that stakeholders again reported back in the workshop. In the afternoon stakeholders developed 4 storyboards to combine ideas from the first one and half days. Use cases were prioritized, then 4 groups took the 4 highest priority use cases and constructed storyboards for them. Workshop outputs included use case précis that were again revised and elaborated with storyboards and a significantly revised system context diagram.

3.1 Exploratory Creativity with Analogies

To support exploratory creative thinking using the analogical museum exhibition and TV program scheduling domains, we drew on lessons learned from previous projects in which stakeholders generated new ideas by transferring ideas from source domain to target domain. Both EASM analogies were carefully selected based on domain analyses, undertaken by the facilitators again using existing EASM documents and specifications, to form domain abstractions. To do this the facilitators drew on the NATURE domain theory [20] that defines a large set of domain categorisations. The analogies were selected to focus on different but key elements of the EASM domain. Once an abstraction of the relevant part of the EASM domain had been formed, the facilitators searched for other business and transport domains that both shared these abstractions and, where appropriate, introduced new working practices and computerized solutions to the other domain. Experts from these domains were then requested to take part as consultants in the creativity workshop. The first analogy with the museum exhibition domain shared was analogous with airspace management as both manage and layout finite physical 3-dimensional space to optimize the achievement of domain-specific goals. The second analogy with TV programme scheduling was analogous with airspace management as both instantiate the resource scheduling abstraction [20]. It also shared surface similarities with airspace management. This was deliberate. Evidence from cognitive psychology suggests that similarity-based reasoning is difficult [5], and that people often need syntactic similarities between domains to recognize analogical mappings [20].

On day-1 a curator from London's Science Museum gave a 45-minute presentation on the design of one of the museum's exhibitions (a period of incubation). The facilitators then guided a group process to externalize analogical mappings before stakeholders worked in 4 groups of 4-6 to discover new ideas using the mappings (illumination). The aim of the expert presentation was to encourage stakeholders to unconsciously and consciously form analogical mappings. On day-2 an expert from a television company gave a 45-minute presentation on problems, issues and solutions to TV programme scheduling (incubation) before the facilitators guided group discovery and externalisation of analogical mappings, then stakeholders worked in 4 groups of 4-6 to discover new ideas using the mappings (illumination).

In both workshop periods, facilitators encouraged analogical reasoning in 2 stages:

- Identify and list mappings between agents, objects, actions, constraints and goals in the 2 domains;
- Use each mapping in turn to generate one or more new ideas about the future EASM system by transferring knowledge about solutions from the museum exhibition design and TV program scheduling domains.

To support this process the facilitators used a simple example of analogical reuse. All new ideas were recorded on cards and shared between the 4 groups at the end of the activity via report back presentations.

3.2 Transformational Creativity

During transformational creativity, people change the solution space in a way that things that were considered impossible are now possible. On the morning of day-1 we encouraged transformational creativity by explicitly guiding stakeholders to discover and remove constraints on the EASM system design. One facilitator led a group brainstorming session to discover as many constraints as possible. Stakeholders then worked in 4 groups to select constraints in turn until none remained, then envisaged the removal of each constraint to generate new EASM ideas based on this removal. The session ended with the groups reporting new EASM ideas and posting them on the ideas boards, which in turn led to a final period of group brainstorming using the new ideas.

3.3 Combinatorial Creativity

Combinational creativity is the creation of new ideas from combination and synthesis of existing ideas. It is the act resulting from an unusual combination of existing concepts [2]. On the afternoon of day-2, storyboarding was used to elaborate and combine creative ideas in the last period of the workshop. Stakeholders worked in 4 groups. Each group was asked to produce a storyboard that described the possible combination of requirements and ideas associated with one use case during the first 3 periods of the workshop. To structure the storyboarding process, each group was given A1-size pieces of paper that were annotated with 16 boxes to contain a graphical depiction of each scene of the storyboard and a space to describe that scene.

3.4 Research Questions

We used data gathered during the workshop and at the end of the requirements process to investigate two research questions that our work had previously failed to answer:

1. During exploratory creativity, did ideas generated from analogical reasoning have an impact on requirements in the final OCU specification?
2. Did ideas generated from and documented after the creativity workshop have an impact on requirements in the final OCU specification?

Our rationale for the first question was to determine whether analogical reasoning is a cost-effective creativity technique. Analogies take time and resources to set up and deliver to a workshop, and results from previous workshops revealed stakeholder difficulties when reasoning analogically [12] and inappropriate analogies when domain assumptions and project scope change [11].

Our reason for exploring the second question was simple – to use the shortened RESCUE process to explore the impacts of ideas from the creativity workshop on the final OCU specification. In spite of anecdotal evidence of impact obtained in previous projects, no stronger evidence had been collected.

We investigated these 2 questions by analyzing the number of ideas generated by the different techniques. At the end of the EASM project we elicited data from the EASM systems engineers to determine whether ideas were novel in the EASM domain, novel to the stakeholders involved in the reported requirements process, and useful for the EASM system according to these stakeholders.

4. Workshop Results

The workshop took place and ran to schedule, and all activities were followed without disruption. We handled minor conflicts about requirements and ideas with facilitated discussion during the report back presentations and verification activities.

The main outcomes are summarized in Table 1. Overall the workshop generated 145 ideas over the two days. It produced 28 new EASM ideas from the day-1 brainstorming session, another 94 by identifying and removing 34 constraints on the EASM system, 15 ideas from analogical reasoning with museum exhibition design, 8 ideas from television program scheduling, and 4 large storyboards. As Table 1 shows, almost half of the brainstormed ideas and all of the analogical ideas were attributed to use cases displayed on the pin boards. In contrast all 94 constraint-based ideas were attributed to the EASM system rather than specific use cases, due to the number of ideas generated, the time available to report them back to the groups, and the lack of time for stakeholders to attribute these ideas to individual use cases.

Deliverable type	Number system-wide	Number use case-specific
Brainstormed ideas	16	12
EASM constraints	34	0
Ideas from EASM constraints	94	0
Ideas from analogical reasoning with museum exhibition	0	15
Ideas from analogical reasoning with TV program scheduling	0	8
Workshop1 storyboards	0	4 storyboards

Table 1. EASM workshop showing the numbers of outcomes for the EASM system and per use case

4.1 Brainstorming

The 30 minute brainstorming session on day-1 generated 28 ideas. A post-workshop analysis by the authors revealed that 20 of these ideas described abstract goals of EASM, such as *provide cross-border working with other EU countries* and *situation too complicated, so need flexible negotiation made simple*. Another 2 describe possible project strategies to achieve these goals, such as *remember that EASM is a means to an end…. do not demand new technologies*. Only 2 described more detailed candidate EASM design features. The first was *simplification of route classification: routes are either permanently available or temporary routes (rigid route with variable operating time): Do away with CDRs 1, 2 and 3, weekend routes, etc*. The second was *record real time activity with a TSA using radar data*. Of the remaining 4, two specified constraints such as *EASM solution must be affordable*, and two challenged the current EASM scope, such as *change current time frame – more flexible time frame*. Overall, the 30-minute brainstorming session accounted for 21% of all results documented on ideas cards over the 2 days of the workshop.

4.2 Removing Constraints

Identifying and removing EASM constraints to discover new ideas also took place on the morning of day-1. Firstly the stakeholders worked together to discover 34 constraints on the design of the EASM system. These constraints were then divided between 4 groups, each containing 4 or 5 stakeholders. The groups worked in parallel to brainstorm 94 separate EASM ideas that became possible if a selected constraint was removed. A final report back session provided more opportunities for brainstorming across the 4 groups.

Removing constraints led to the generation of new EASM ideas. For example, removing constraint *[C2] categorization of routes* led to the generation of 3 ideas: (i) *simple method of routing from A to B*; (ii) *all routes always open unless notified as closed*; (iii) *free flight – do we need a rigid route structure, and flight level constraints?* Each of the ideas explores candidate EASM requirements in a space of possible requirements for the new system.

Removing other constraints sometimes led stakeholders to consider trade-offs between the satisfaction of competing goals and constraints. For example, removing constraint *[C3] revenue protection*, led to the generation and documentation of advantages of the constraint's removal: (i) *improved efficiencies of traffic flows*; (ii) *reduced delays through wider distributions of traffic*; (iii) *better utilization of resources between air traffic controllers*. Elsewhere, removing other constraints led stakeholders to consider the possible advantages and disadvantages of EASM ideas. For example, removing constraint *[C18] location of military bases difficulties and politics* led to advantages such as *reduced training times to transit areas* and *increased access to airspace with bigger areas available*, but also disadvantages such as *higher data integrity that is difficult to achieve*, *the inability of humans to detect system errors*, and *deskilling of the human*. As such the stakeholders explored trade-offs between soft goals that are more commonly expressed with notations such as *i** soft goal contribution links [22].

In conclusion, the most prominent result was the number of ideas and advantages and disadvantages that were generated in a one hour period. Our method counted recorded advantages and disadvantages as ideas, which can explain the larger total of ideas arising from constraint removal.

4.3 Analogical Reasoning

After the expert presentation on museum exhibition design on day-1, the stakeholders generated analogical mappings between actors, objects, actions, goals and constraints in the museum exhibition and EASM domains. The mappings identified by stakeholders are listed in Table 2. Whilst some of the expected mappings were externalized, stakeholders did not externalize all of the mappings, such as *visitor* to *aircraft* that the facilitators considered as obvious during preparation of the workshop.

Museum Exhibition	EASM
Explicit decision making	Within time
Barons	National states?
Types of users	Recreational users as well
Vista from different perspectives	Network effect
Argument discussion	Principles, same rules, Arbiter
Creative vs. engineer tension	Try, try and try again
Dislocate expectation	New approaches
Spine	Optimal routes
Take time to review decisions	
Sponsors	Big states support
Numbers through the door	Measures of EASM success
Creative design	Network manager process
Pictorial information	Visualizations
Tensions	Tensions
Education – pre-emptive thinking	Less done in ATM

Big picture – incremental small drops	Promise on capacity + delivery
Known constraints	Constraints
Environment constraints	Environment constraints, balance
Miscommunication of concepts	
Fine space (i) Deviate to achieve goal; (ii) 3D space; (iii) Manipulate model and simulate	Finite space (i) More space levels; (ii) Flows on 1D; (iii) Simulate
Turkish delight	

Table 2. Analogical mappings between the museum exhibition design and EASM domains

The facilitators then divided the stakeholders into 4 groups of 4 or 5 to generate new EASM ideas using these mappings. Each group worked for 40 minutes to illuminate up to 3 ideas each and document them using analogical idea cards. The 4 groups defined 15 atomic ideas. Three ideas were:

- *The need for a pan-European airspace management cell to make decisions on airspace requests based on protocols and procedures* – an analogical idea based on *how political battles for exhibition space in the museum are resolved;*
- *The need to take into account the needs of different users such as civil ANSP, military ANSP and customers* – an analogical idea based on *how the museum exhibition is designed to educate different groups of visitors;*
- *The need to consider and meet the needs of different user groups using clear priorities* – an analogical idea based on *strategies that museum uses to allocate space to different groups such as fee-paying business diners.*

The other 12 atomic ideas are summarized in Table 3.

Use 3D spaces that show time-peak flow optimum airspace sharing, e.g. of the Scottish TMA ACP – analogous to how museum space and constraints are used
Control the regulation at regional airports – again analogous to how museum space and constraints are used
Divert aircraft flows away from constraints, offer sufficient incentives for operators to do so, and allow airlines to pay for optimal routes – analogous to museum strategies for diverting flows to and from objects, and fast tracking museum visitors
Focus on the main system goals – analogous to the curator achieving his goals and not being deflected from them
Use of EASM computer models and real-time simulations and trials, analogous to the use of gallery mock-ups and other artefacts
Provision of incentives and buy-ins to all departments to ensure EASM 's success and avoid factional interests dominating, analogous to how museum curators work together to avoid factional infighting
Establish long-term and medium term visions and plans over and over again with EASM, analogous to the activities that led to the best positioning of an aircraft in an exhibition
EASM shall deliver simple solutions that avoid complications and accept inputs from sources that do not deviate from EASM main objectives, analogous to the use of the museum 'spine' structure in managing an exhibition space
All European states must agree similar protocols, analogous to how political battles for exhibition space in the museum are resolved
EASM should support explicit decision making about air space use by one UK air space manager,
P&P process to be developed and agreed at a collaborative level to enable civil and military AMC airspace managers to decide on the allocation of air space
EASM space allocation to be done if it is timely, and avoided if it is too late to be effective, analogous to the use of decision making to timelines in museum exhibition design

Table 3. Other EASM ideas generated from the museum exhibition design analogy, reworded to improve their comprehension in this paper

After the expert presentation on TV program scheduling on the morning of day-2, the stakeholders generated analogical mappings between actors, objects, actions, goals and constraints in the TV scheduling and EASM domains. All of the analogical mappings generated during the mapping brainstorm period are listed in Table 4. The larger number of externalized mappings was a response to mappings that were not externalized for the museum exhibition design analogy. The facilitators decided to spend more time externalizing more mappings.

TV Scheduling	EASM
Horizontal scheduling Vertical scheduling	Visible to all by time
Schedule publication set time	
Audience research figures	EC function: (i) UK scheduling activity for civil; (ii) Patterns of military use
Perturbations	To be able to handle cultural trends, weather serviceability
Measured and monitored	Update
Habit – forming	Stable habits
	Stability durations – what are drivers and constraints
Expectation management	Not solve all
Avoid soap clashes	(i) Airlines co-ordinate schedules; (ii) Carrots and sticks
Global co-operation	Publish schedules
PR wins	Military space awarded
Visualization of schedules - what data	Quick, use graphic for users? For who?
Contingency templates	(i) Failure types; (ii) Strikes incidents; (iii) Drop low priority activities; (iv) Get it improved, who?
Mini – adverts - credit	Advertise to people for who - military UC 11 traffic planner
We know what they are - lingua franca	Lingua franca
Extreme emergencies Support rescheduling	Shut off the danger areas; (i) Consistent; (ii) Notification; (iii) Processes
Increased commercials	Resizing the space?
Complementary scheduling	Alternatives to be provided
Keep the audience	Keep the civil, keep people engaged
Flexible start times	More tactical airspace management
Promotions (adverts)	Promotion, new alternatives incentives
Purchase of programs	
Sky+ - you can extend your day	Adapt strategies to handle new technologies - flexibility "stop time"
Look across boundaries to see each other's space	
Commercial- program dependence Both a public service	Military – civil dependence

Table 4. Analogical mappings between the television program scheduling and EASM domains

As in day-1, stakeholders worked in groups of 4 or 5 for 40 minutes to illuminate up to 3 ideas each and document them using the analogical idea cards. Overall the 4 groups identified a total of 8 atomic ideas. Two example ideas were:

- *Introducing collaborative decision-making in response to the realization that not all airspace users can win all of the time, then using benefits to these users both strategically and tactically in decision-making;*
- *Providing segregated airspace with defined volumes when needed (as opposed to all of the time) to military users for specified time periods to enable specific missions to be completed successfully.*

Space constraints preclude us from listing the other 6 ideas. Overall however, in spite of the longer and more explicit analogical mapping process led by one of the facilitators, the larger number of surface similarities known to aid analogical reasoning [19] and the clear presentation given by the expert, the TV program scheduling analogy led to fewer documented ideas than the first one.

Evidence was sought for the impact of ideas from the two analogies on subsequent storyboarding. Stakeholders had associated analogical ideas with *UC4 Assess*, two with *UC11 Display AS utilization/availability information*, one with *UC5 Negotiate*, and none with *UC7 Disseminate in-*

formation. Post-workshop analysis of each storyboard revealed the impact from some but not all of the ideas. For example, the idea *Y6 types of users; satisfy all users – if not prioritize* was elaborated in the *UC4 Assess* storyboard in Figure 4 – the bottom half of the storyboard shows *request inputs from air force and navy users* (on the left-hand side) and *civil airspace users* (on the right-hand side), *generating notification of multiple route options based on use choices* (at the bottom). Another idea – *Y8 keep the ideas simple .. allow input from other sources but remember the goal* – was elaborated in the same use case. Again the bottom half of the Figure 4 shows a *collocated MABCC and TM feeding into the new AMC function* – the core of the agreed simple idea. A similar pattern of impacts from analogical ideas was shown for *UC11 Display AS utilization/availability information*.

4.4 Use Cases and Storyboarding

On the afternoon of day-2 the 4 stakeholder groups combined ideas from the physical use case pin boards to produce 4 storyboards for the 4 prioritized use cases using structured but blank storyboards. Stakeholders used these sheets in different ways as shown in Figure 2. The left-hand side shows an annotation of the storyboard produced for the *UC5 Negotiate* use case. The storyboard was originally produced using large number of coloured stickies for each sentence to make the storyboard and flows as dynamic and flexible when producing the storyboard. At the end of the workshop the storyboard was immediately redrawn by the facilitators to make the result permanent, and no photograph of the original remains. The right-hand side storyboard shows what is, in essence, a complex flow diagram with EASM system inputs on the left and outputs on the right. The original storyboard was extended physically to the left with additional sheets containing extra information. The bottom part of Figure 3 shows a more complex flowchart that was produced on the backside of 2 storyboard sheets to depict a storyboard for the use case *UC4 Assess*. These examples show the range of storyboard representations used without direct prompting from the facilitators.

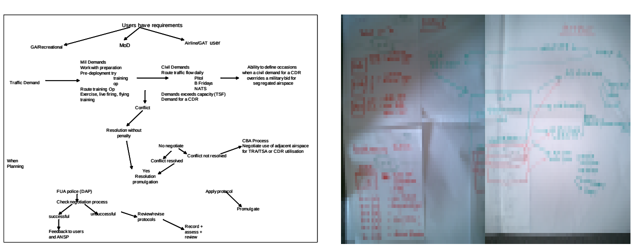


Figure 2. Different styles of storyboards developed

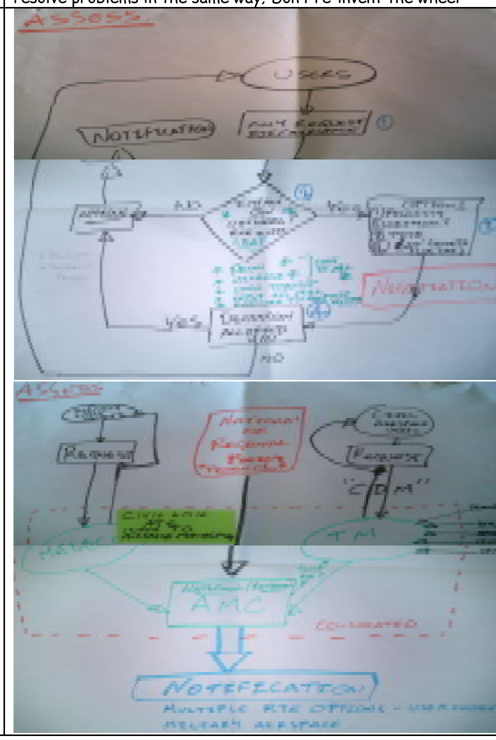
Use Case Name	*Assess*
Précis	The MABCC 'part' of the AMC Function assesses the relative priorities of Military bids for MDAs. Flow and Traffic Management assess forecast traffic flows and weather information to determine the requirement for routings and/or alternatives within appropriate AS.
Actors	FMP/TM, AMC function
Idea Cards	**W16**: Make sure airspace is used; efficient use of airspace; reduce fragmentation. **W17**: Simplification of route classification; Routes are either permanently available or temporary routes (rigid route with variable operating time); Do away with CDRs 1,2,& 3, Weekend routes, etc **Y3**: Focus on the aim **Y5**: All the departments had an incentive to make the system successful in the end otherwise factional interests will compete; Give the stakeholders a reason to buy in; Focus on the big picture; Carrot and stick **Y6**: Types of users; Satisfy all users – if not prioritize; Determining priorities **Y8**: Keep the idea simple; Don't let other aspects over complicate a idea/aim; Allow input from other sources but remember the goal **Y9**: Explore ideas in place already in place applying to UK; Look for similar problems already being resolved and see if you could resolve problems in the same way; Don't re-invent the wheel
Storyboards	

Figure 3. The description of the *UC4 Assess use case* at the end of the workshop

Figure 3 shows the state of the use case *UC4 Assess* at the end of the workshop. The original input to the workshop was a simple précis of 39 words shown at the top of the use case. Figure 3 shows that the final use case included 7 related new ideas, and a storyboard all placed on the ideas board for the use case. The engineer charged with development of detailed use case specification was later able to use them to determine allocation of work to different actors, action ordering, and the nature of interaction between systems and people. Four such use case descriptions were developed by the workshop end.

5. Idea Novelty and Usefulness

At the end of the requirements process the EASM team developed an OCU specification. We worked with EASM experts to review the impact on the specification of ideas generated during a creativity workshop. All 145 ideas summarized in section 4 were extracted from the workshop report. We developed a simple framework to review each idea using two criteria derived from Sternberg's [21] definition of creativity: "*the ability to produce work that is both novel (i.e. original, unexpected) and appropriate (i.e. useful, adaptive concerning task constraints)*".

The first criterion was applied to rate the novelty of each idea. Boden [2] describes how creativity exists at different levels, for example the personal, psychological and historical. We built on these differences to define creativity in the EASM project as an idea that is novel to the EASM domain and project, rather than novel to all air traffic management systems and projects. We developed a simple three-point scale to rate the novelty of each idea – 1 indicated that all elements of the idea were novel in the EASM project and domain; 2 indicated that some elements of the idea were novel; and 3 indicated no novelty.

The second criteria recorded the usefulness by investigating the impact of the idea on the OCU specification. Again a simple three-point scale was adopted for each idea – 1 indicated that the idea had a major impact on requirements in the specification; 2 indicated that the idea had some impact on the final specification; and 3 indicated that the idea had no impact on the final specification.

We investigated the novelty and usefulness of each idea using expert opinion during a two-hour meeting at the end of the requirements process. The core team of 2 systems engineers ranked each workshop idea independently for its novelty and usefulness. A follow-on e-mail dialogue then elicited additional opinions from the experts as required. For all but one idea, the two engineers were able to reach agreement about the two-part rating of each idea. One alternative option was to ask independent experts from outside the project to rank the ideas. However, no such experts were available. Indeed, given the specialist nature of enhanced airspace management, available experts were expected to participate in the requirements process and creativity workshops.

Rating results are reported in Table 5. During the rating process, one brainstorming idea was allocated 2 alternative usefulness ratings, and 4 other items from the brainstorming analogical sessions were not assessed as the experts were unable to review them adequately. Overall, from the remaining 139 ideas rated, the two experts only rated 2 ideas – one from the brainstorming and one from constraint removal – as being completely novel. A further 40 ideas – 10 from brainstorming, 9 from analogical reasoning and 21 from constraint removal – were rated as being novel in at least one element. Of the 97 ideas rated as not novel, 67 were generated during constraint removal and described advantages and disadvantages of constraint removal as well as ideas themselves. Overall, almost 70% of the ideas results from the creativity workshop were creative.

In contrast, 106 (76%) of the ideas were rated as having at least some impact on the OCU specification. Twenty-one (75%) of the ideas generated during brainstorming, 17 (74%) from analogical reasoning and 68 (76%) from constraint removal had some impact.

Technique	Novelty			Impact		
	1	2	3	1	2	3
Brainstorming	1	10	16	11	10	7*
Science Museum Analogy	0	7	8	7	5	3
Programme Scheduling Analogy	0	2	6	2	3	3
Constraint Removal	1	21	67	8	60	21
Totals	2	40	97	28	78	34

Table 5. Totals of ideas ranked for novelty and usefulness. * denotes one idea given a second usefulness rating

We investigated the 2 ideas rated as completely novel. The first – *make decisions any time; increase size of areas available* – was also rated a having a significant impact on the OCU specification. During follow-up questions one of the two systems engineers characterized the idea as: *"not specifically referred to in a single sentence, (the requirement is a vein running through the whole text) ……".* The other idea – *military to get to training areas within time, so subsidize military to travel further = problem of extra transit time* – was rated as having no impact on the OCU specification. The same systems engineer reported that: *".. because it would be extremely complex to initiate - who would pay …. It may come to fruition some time in the future".*

Table 6 reports the distribution of 36 ideas that were rated as both novel and useful by technique. Brainstorming generated 5 ideas ranked as useful and partly novel, including: (1) *simplification of whole process to enhance safety, one block of air space;* (2) *change the current time frame – more flexible time frame*, and; (3) *distribute information to databases belonging to someone else*. Constraint removal generated 4 ideas ranked as useful and partly novel, including *system-wide information management* and *real-time notification of airspace availability*. These examples demonstrate that most ideas described concepts, and occasionally goals, that were later refined using storyboards and use case specifications, rather than as concrete requirements that engineers might express using VOLERE shells and trace using standard traceability techniques. Results also reveal differences between the two analogies. The museum exhibition analogy led to 6 ideas that were both novel and useful whereas the TV program scheduling analogy only generated 2.

Technique	Novelty rating	Usefulness rating: Full	Usefulness rating: Partial
Brainstorming	Full	1	0
	Partial	5	4
Science Museum Analogy	Full	0	0
	Partial	3	3
TV Program Scheduling Analogy	Full	0	0
	Partial	1	1
Constraint Removal	Full	0	0
	Partial	4	14

Table 6. The numbers of ideas ranked as both novel and useful by the technique used to discover them

Finally, not shown in Table 6, the systems engineers rated 12 ideas (5 from brainstorming and 7 from analogical reasoning) as being useful but not novel in any way. This demonstrates that the workshop acquired and assimilated useful ideas that were both novel and unoriginal.

6. Research Questions Revisited

EASM stakeholders regarded the creativity workshop as a success. The workshop delivered use case descriptions supported with complex storyboards. The EASM team later used these deliverables to generate the OCU specification for the EASM system. Workshop results and data gathered at the end of the process enable us to answer the research questions:

1. During exploratory creativity, did ideas generated from analogical reasoning have an impact on requirements in the final OCU specification?
2. Did ideas generated from and documented after the creativity workshop have an impact on requirements in the final OCU specification?

To answer the first question, data gathered after the EASM process ended indicated that the two analogies resulted in the generation of fewer novel ideas than other techniques, and that these ideas were rated as being less novel and useful for the OCU specification. Indeed, to our surprise, more facilitation of one analogical domain with more surface similarities to the EASM domain led to fewer ideas that were rated as novel and useful. A qualitative analysis revealed that some ideas did have an impact on subsequent storyboards generated for 4 more important use cases. That said, exploiting one-off depth-first analogies that are mapped out prior to a workshop might not be as effective as hoped, as analogical reasoning occupied 2 of the 4 workshop sessions but only delivered 15% of the ideas. Alternative strategies for more effective analogical reasoning are discussed later.

To answer the second question, data gathered after the EASM requirements process ended indicated that, overall, creativity workshop ideas did impact on the requirements in the EASM specification. According to EASM systems engineers, 106 of the 139 ideas (76%) impacted on the final specification, with 28 of the 106 being rated as having a major impact. Results indicate that outcomes from the single two-day workshop held four months into the project informed much the subsequent requirements work for the subsequent eight months. That said, results also reveal that only 42 of the 139 ideas were perceived as have some degree of novelty (30%), with only 2 ideas being rated as completely novel. On the surface, this would suggest that the workshop was less successful at generating large numbers of very novel ideas, which is consistent with Boden's definition of historical creativity [2]. Rather it suggests that the workshop was effective at both inventing new ideas and surfacing requirements known but not documented prior to the workshop. One reason for this might have been the use case descriptions that structure workshop ideas in a form that makes them directly applicable during system specification, but we have no evidence to support this claim. Not all of the useful ideas were novel, but then not all requirements were expected to be original, so we should expect stakeholders to contribute such ideas during creativity workshops. Indeed, given their duration – 2 days in a 12-month project – creativity workshops have the potential to be cost-effective mechanisms for discovering both novel and unoriginal requirements. Creativity workshops can aid specification of both new systems with few constraints and systems that are constrained by existing systems or domains that do not allow for new ways of working.

There are several threats to the validity of the expert ideas ratings that warrant discussion. The first is the 8-month delay between the idea being documented in the workshop and rating the idea at the end of the process. Over these 8 months, the systems engineer's understanding of EASM increased (both were recognized as European experts by the end of the project), hence had they rated the ideas immediately after the workshop, their ratings of idea novelty might have been higher. The second threat is the potential bias from the presence of two of the authors during the meeting in which the ideas were rated. Given the author's involvement in the design of the workshop, the systems engineers might have been influenced to rate ideas as more novel and useful. However, the results reveal little evidence of this in the novelty ratings, in part because these two engineers took ownership of many ideas after the workshop and the role of the authors in the process was perceived as small.

7. Lessons and Future Work

Results indicate that RESCUE creativity workshops have the capacity to discover both novel and unoriginal ideas that can be integrated into use case descriptions and storyboards so that the majority of the ideas are useful later in the process of specifying the software system and its use, although further studies are needed to confirm this conclusion. The EASM workshop reported in this paper also gave rise to 3 lessons that can inform our and readers' creative requirements processes.

Firstly, the ideas generated in the workshop revealed that stakeholders often manipulated abstract goals and complex concepts, such as *flexible negotiation made simple* and *methods of routing*, rather than more concrete requirements that methods such as the UML can represent, model and trace. The integration of concepts in *UC4 Assess* in Figure 4 provides evidence of this. Although the *i** approach can represent and reason about abstract goals [22], requirements methods still need new techniques to deal with core concepts, similar to the use of concept studies in systems engineering.

Secondly, constraint removal led stakeholders to consider the advantages and disadvantages of possible new concepts and ideas, but without an explicit structure to do so. One option is to introduce simple, graphical design rationale techniques [23] during constraint removal to record and report argumentation structures. The use of more structured representations will require the use of trained scribes, which can also overcome the problem of recording results of idea ‘blizzards’ such as that encountered during constraint removal. The large number of ideas was generated too quickly to attribute them to use cases – more trained scribes can support this process.

Last but not least, our use of analogies needs to be made more cost-effective to justify inclusion in workshops. This paper provides concrete evidence to support anecdotal observations from earlier workshops – stakeholders often failed to exploit the analogies carefully designed using NATURE’s domain categorizations [20]. Possible reasons include an insufficient number of idea sources from one analogy (e.g. the TV programme scheduling domain simply offered too little innovation to prompt ideas in the EASM domain), people often interpret analogies in ways that were not predicted, and human abilities to reason analogically vary by individual. In future workshops we will explore new strategies. These include offering stakeholders more than one analogy from a library of similar domains, and using multi-media descriptions of these domains to impart domain knowledge that can be exploited during incubation and illumination activities. We see this as part of a more incremental process to exploring and selecting analogical domains interactively with stakeholders, and would begin prior to creativity workshops to ensure that the right experts in involved in them. In simple terms, we will exploit stakeholders’ domain expertise in choosing and refining which analogies to exploit. We look forward to reporting results from these new, improved workshops in the future.

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