

Model-Driven Requirements Engineering with *i*:* Synchronising Models in an Air Traffic Management Case Study

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Two-Part Presentation

Process and its application

RESCUE process
DMAN project and its *i** models

Case study findings

Synchronisation checks applied
Results from synchronisation checks



RESCUE Requirements Process



Challenges

- How to scale established research-based techniques such as *i** to large socio-technical systems?
- How to synchronise the use of these techniques towards new integration theories?

Explored through case study research



The Departure Manager (DMAN) System

Departure manager for major European airports

- Sponsored by Eurocontrol
- Applied RESCUE over 12-month period
- Joint project involving UK and French national bodies
- Applications including Heathrow and Charles de Gaulle



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# **RESCUE: Human Activity Modeling**

|                        |                                                                                                | W02CUL0_3 HAM.doc                                                 |
|------------------------|------------------------------------------------------------------------------------------------|-------------------------------------------------------------------|
| HAD5                   | Pilot calls GMC to request cleanance to push back                                              |                                                                   |
| Author                 | wwwwww                                                                                         |                                                                   |
| Cote                   | 0000000                                                                                        | 4. The strip has information printed on it:                       |
| Source                 | Observations and interviews 6/3/03 and 2/4/03                                                  | 4.1. SID-3 letter code not designator                             |
| Actors                 | Filot, GMC                                                                                     | 4.2. The number of times the SID has been modified since          |
| Precis.                | www.www                                                                                        |                                                                   |
| Gaols                  | Pilot given push back deprance                                                                 | inception                                                         |
|                        | Timely push back dearance given                                                                | 4.3. Slot time                                                    |
|                        |                                                                                                | 4.4. Squawk                                                       |
| Semantic               | Knowledge of different factors regarding air anaft types; Knowledge of different               | Cognitive actions - read strip information, recognise information |
| knowledge              | foctors and issues regarding airfield.                                                         | missing / incorrect / unusual                                     |
| Triggering             | Pilot requests push back dicarance                                                             | 5. ATSA checks for slot time against the DSM                      |
| event<br>Descendiaises |                                                                                                | Resources - strip, DSM system                                     |
| Preconditions          | Pilot is ready to push back                                                                    | Physical actions - enter information into system                  |
| Assumptions            |                                                                                                | Communication - interact with system, read information            |
| Normal course          | 1. Pilot colls for push back                                                                   | Cognitive actions - search / find / read system information,      |
|                        | <u>Resources</u> - rodio, heads et                                                             | compare printed strip information with system information,        |
|                        | <u>Physical actions</u> - flick radie transmission switch, move to look out of window, look at | recognise information different                                   |
|                        | oirfield and air craft, hear pilot call                                                        |                                                                   |
|                        | <u>Cognitives clians</u> - recognises ir oroft, not drair oroft with strip                     | 6. ATSA passes strip to GMP                                       |
|                        | 2. GMC locates strip in bay                                                                    | Resources - strip                                                 |
|                        |                                                                                                | Physical actions - move strip to another desk / controller        |
|                        | 3. If appropriate , GMC gives push back dearance                                               | Cognitive actions - recognise when to pass strip to next          |
|                        |                                                                                                | controller                                                        |
|                        | 4. GMC puts strip in push back position in bay                                                 | <ol><li>GMPputs the strip in the relevant bay</li></ol>           |
|                        | www.ww                                                                                         | Resources - strip, strip bay                                      |
|                        | 5. Pilot starts engine and does manual checks                                                  | Physical actions - move strip to required position in bay         |
|                        | wwwww                                                                                          | Cognitive actions - acknowledge new strip, read strip             |
|                        | 6. Pilot pushes back air araft                                                                 | information, decide on which bay position to place strip          |
|                        | 0000000                                                                                        | Resource Mgmt strategies - strip bays organised into areas,       |
| Differences            | 4. For some controllers, push back dearance is given to different air araft in                 | strips ordered in bays: alphabetically by company name, then      |
| dusto                  | a coordance with the order in which pilots have called; others perform more                    | numerically by call sign, with BA flights separate                |
| variations             | optimisation.                                                                                  | i due to 3. At Gatwick, strips are not printed for arrivals       |
|                        |                                                                                                | due to +5. At Gatwick, stribs are not billited for anivals        |
| Contextual             | 1. Efnight time                                                                                |                                                                   |
| features               | <ol> <li>Loadion is validated via pilot confirmation of position and SMR system</li> </ol>     |                                                                   |
|                        |                                                                                                | DD-bage document                                                  |
| Constraints            | Boysize - limited space for strips                                                             |                                                                   |
|                        | Noise levels - printer , system alar ms, people talking                                        | 55-page document,<br>15 AS-IS scenarios                           |
|                        | Staff shortage                                                                                 | DAS-IS scenarios                                                  |



### **RESCUE: Use Cases and Scenarios**

#### Use case specification of system behaviour – Supported with ART-SCENE scenario walkthroughs

|                  |                                                                     | 000                 |                    |                                                | @ AR                                                                             | RT-SCENE So     | enario F       | Presenter                                                                                |                             | $\Box$                  |
|------------------|---------------------------------------------------------------------|---------------------|--------------------|------------------------------------------------|----------------------------------------------------------------------------------|-----------------|----------------|------------------------------------------------------------------------------------------|-----------------------------|-------------------------|
| VCD3             | Give push back clean ance                                           | Back Forwa          | ard Sto            | C C m                                          | AutoFill Print Mail                                                              |                 |                |                                                                                          |                             | Ø                       |
| Author           |                                                                     |                     | ttp://hoidpr       | roj.soi.city.ac.uk/scenariop                   | resenter /main.asp                                                               |                 |                |                                                                                          |                             | > go                    |
| Cote             |                                                                     | ADT CCE             |                    | leenenie D                                     |                                                                                  | Domain          | Name:          | Use Case Name:                                                                           | Use Communic                | 5 Context: At satellite |
| Source           | RESCUE stage 1                                                      | ART-SCE             | INE S              | Scenario Pi                                    | resenter                                                                         | DM              |                | GivePushbackClearance                                                                    | Case:1 Scenario             | airport                 |
| Actors           | Pilot, Ground ATCO                                                  |                     | Normal C           | Course  Action Type                            | + E<br>Description (Natural Language)                                            |                 |                | ive Course for Event 1<br>Description (Natural La                                        | + E - C                     | IR                      |
| Problem          | Need to improve the way in which dearances to push back fro         |                     |                    | nunication The pilot c                         |                                                                                  |                 | C26.1          | What if the radio frequency is congested                                                 |                             | Bh                      |
| statement        | given to assist runway sequencing                                   |                     |                    |                                                | uests pushback from the Ground ATCo<br>ATCo looks for the flight information o   |                 | C26.2          | What if the radio message is interrupted                                                 | d?                          | <u>a</u> ll             |
|                  | green to assist harway stepped and you                              |                     |                    | controller di                                  | splay                                                                            | -               | C26.3          | What if the radio is unavailable?<br>What if the radio fails?                            |                             |                         |
| Presis.          |                                                                     | Main Menu           | / 0                | ognitive The Ground<br>is OK to Pus            |                                                                                  | ght in DMAN     | C26.3.1.1      | What if the radio system fails?                                                          |                             | 2                       |
|                  | 0000000                                                             | 9                   |                    | hysical The Ground                             | ATCo looks at the aircraft and nearby 1<br>ATCo decides that the flight can push | traffic E       | C26.3.2        | What if the radio channel is blocked?                                                    |                             |                         |
| Triggering event | Pilot requests push back diegrance                                  |                     | 13 Comr            | munication The ground                          | ATCo gives the pushback clearance to t                                           | the other       | EC26.5<br>SAC1 | What if the incorrect radio frequency is<br>What if this action does not complete?       | used?                       |                         |
| Preconditions    |                                                                     |                     | 15 Comr            | munication The pilot ac                        | knowledges the clearance                                                         |                 | SAC10          | What if the end of this action is delayed                                                | 1?                          | ăl                      |
| Assumptions      |                                                                     | All<br>Requirements | 19 Comr            | munication The Ground                          | ATCo enters pushback given to DMAN I                                             |                 | SAC11          | What if the information manipulated in                                                   | this action is out-of-date? |                         |
| Assumptions      | vvavvavv                                                            | Normal              | 21 5               |                                                | he electronic strip<br>is the time of the pushback clearance :                   |                 | SAC12<br>SAC2  | What if the information manipulated is<br>What if there is insufficient information      |                             | × ×                     |
| 000000           |                                                                     | Requirements        |                    |                                                | status to Cleared to Pushback                                                    |                 | SAC3           | action?                                                                                  |                             |                         |
| Normal course    | 1. The Pilot calls the Ground ATCO and requests push back           | Alternative         |                    | Physical The aircraft                          | pushes back                                                                      |                 |                | What if the information manipulated in<br>some way?                                      |                             |                         |
|                  | 2. The Ground ATCO looks for the flight info on the DMAN d          |                     | 27 Comr<br>29 Comr | munication A-SMGCS ic<br>munication A-SMGCS se | entifies the pushback of the aircraft<br>ends flight status message to DMAN      |                 | SAC4           | What if the information manipulated in<br>for the task?                                  |                             | 8                       |
|                  | 3. The Ground ATCO checks that the status of the flight in [        | Requirements        | 31 S               | System DMAN updat                              | es the status of the flight to Pushing b<br>s that other MOBT & MTOT times are s | still officient | SAC5           | What if the information manipulated in<br>for the task?                                  | this action is too general  | 8                       |
|                  | oshi oshi yito yito yito yita sharine sharasorine nigirini t        | All Events          | 35 Comr            |                                                | ble given this pushback time<br>a new updated Estimated Take Off Tir             | G               | SAC6           | What if the information manipulated in<br>some way?                                      |                             |                         |
|                  | 4. The Ground ATCO looks at the air araft and mar by traffic        | Change Style        |                    | or DPI) to T                                   |                                                                                  | G               | GAC9<br>GAG1   | What if this action ends before it is plan<br>What if Pilot is unavailable during this a |                             | ¥<br>▼                  |
|                  | · · · · ·                                                           | Selected            |                    |                                                |                                                                                  |                 | GAG2           | What if Pilot is not functioning during th                                               | his action?                 | ē                       |
|                  | 5. The Ground ATCO decides that the flight compush back             | Alternatives        |                    |                                                |                                                                                  |                 | SAG3<br>SEV1   | What if Pilot is functioning incorrectly de<br>What if this event does not occur in this |                             | 7                       |
|                  | 6. The Ground ATCO gives the push back dearance to the pilo         | Logout              |                    |                                                |                                                                                  |                 | SEV2           | What if this event occurs earlier in time<br>scenario?                                   |                             | 2                       |
|                  | 7. The pilot a denowledge the dearance                              |                     |                    |                                                |                                                                                  | G               | GEV3           | What if this event occurs later in time t                                                | han expected in the         |                         |
|                  | 8. The Ground ATCO checks that the <u>reading to be</u> is correct  |                     |                    |                                                |                                                                                  | G               | SEV4           | What if this event occurs more than one                                                  | ce in this scenario?        | <b>₫</b>                |
|                  | 9. The Ground ATCO enters 'pushback given to DMAN by tou            |                     |                    |                                                |                                                                                  | G               | GEV5           | What if this event occurs less frequently<br>scenario?                                   | y than expected in the      |                         |
|                  | electronic strip                                                    |                     |                    |                                                |                                                                                  | 9               | SEV6           | What if this event occurs more than one                                                  | re in the scenario?         |                         |
|                  | 10. DMAN records the time of push back dearance and updat           | The Centre for HCI  | Design, Cit        | ity University                                 |                                                                                  |                 |                |                                                                                          |                             | Developed By Amit Tosar |
|                  | the flight to Cleaned to Push table                                 | 🕘 http://www.m      | niorosoft.cor      |                                                | •                                                                                |                 |                | 40                                                                                       |                             |                         |
|                  | 11. The Pilot initiates push back                                   |                     |                    |                                                | ILSO C                                                                           | 201             | 0              | s, 13 n                                                                                  | orm                         | า                       |
|                  |                                                                     |                     |                    |                                                |                                                                                  | <b>U</b> D      |                | <del>, 10</del> 11                                                                       |                             |                         |
| Variation 1      | If the air araft is calling too early for its slot, then replace st | an Suith:           |                    |                                                |                                                                                  |                 | •              |                                                                                          |                             |                         |
|                  |                                                                     |                     |                    |                                                | unco (                                                                           | not             | 214            | ons + 3                                                                                  |                             |                         |
|                  | 3.1 The Ground ATCO sees that the status of the flight in D         | NAMIS NOT C         | JK 10              |                                                | JUI SE (                                                                         |                 |                | <u> UIIS T J</u>                                                                         |                             |                         |
|                  | push'                                                               |                     |                    |                                                |                                                                                  |                 |                |                                                                                          |                             |                         |
|                  | 3.2 The Ground ATCO assesses the situation regarding work!          | cad and air an      | oft                |                                                |                                                                                  |                 |                |                                                                                          |                             |                         |
|                  | already remote holding                                              |                     |                    |                                                |                                                                                  | 115             |                | on aver                                                                                  | <u>100</u> 2.               |                         |
|                  |                                                                     |                     |                    |                                                |                                                                                  |                 |                |                                                                                          | ~ ~ ~ ~ ~                   |                         |
|                  | ******                                                              |                     |                    |                                                |                                                                                  |                 |                |                                                                                          |                             |                         |



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# **RESCUE:** *i*\* **System Modeling** SD and SR models, with REDEPEND tool





#### For 7 actors, 103 model elements

15 actors, 46 dependencies



### i\* Modeling: Lessons

### Enhanced process guidance

Extended context models prior to *i*\* system models



- Dependency tables prior to modeling
   Controller depends on DMAN to depart aircraft on time
   DMAN depends on controller to update departure schedule
- Guidelines to focus on goal/soft goal dependencies
- Simple-to-use plug-in to MS-VISIO



**RESCUE: Five Synchronisation Stages** 



### **Some Synchronisation Checks**

Stages 1 and 2: Boundaries and Work Allocation

| Check | Definition                                                                                                                                                                                                         |
|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2.2   | Actors, resources, goals, actions, differences due to<br>variations, and differences due to contextual features in<br>the activity models should appear in relevant use case<br>descriptions.                      |
| 2.4   | All external actors in the i* SD model should correspond to actors in the use case descriptions.                                                                                                                   |
| 2.5.1 | Each low level task (i.e. each task that is not decomposed<br>into further lower-level tasks) undertaken by an actor in<br>the i* SR model, should correspond to one or more actions<br>in a use case description. |



## **DMAN Results**

Synchronisation checks undertaken at each stage

- Stage 1: May 2003
- Stage 2: September 2003
- Stage 3/4: January 2004

Stage 1 and 2 checks

- RESCUE Quality Gatekeeper
- Results reported in detailed check-by-check reports



### **Results from Stages 1/2: Sept 2003**

### Quality Gatekeeper worked for 8 days

- 126 issues from 7 checks
- 113 of these from only 3 checks

| Check | Total | Issues and actions                                                                                                                                                                                            |
|-------|-------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.1   | 3     | Current system activities without use cases                                                                                                                                                                   |
| 1.2   | 4     | Current system actors missing from context model                                                                                                                                                              |
| 1.3   | 21    | * Context model actors and actor links missing from the use case model and, incorrect actor naming                                                                                                            |
| 2.2   | 1     | * Ambiguity in use of contextual variations in use case descriptions detected                                                                                                                                 |
| 2.4   | 37    | <b>*</b> <i>i</i> * model actors missing from the use case descriptions                                                                                                                                       |
| 2.5.1 | 5     | $\star$ <i>i</i> $\star$ model tasks missing from the use case descriptions                                                                                                                                   |
| 2.5.3 | 55    | * Ambiguities needing clarification, missing use case<br>elements, dependencies between use cases discovered,<br>use case decomposition needed, action ordering wrong,<br>missing non-functional requirements |



# Check 2.4

### Check 2.4 (37): Missing actors from UC descriptions – Extend use case specifications for completeness



A-SMGCS

 The pilot is taxiing the aircraft following taxi clearance
 A-SMGCS nonitors the progress of the aircraft and sends the expected time at the Holding Point to DMAN
 DMAN verifies that there are no conflicts between the expected times at the Holding Point and the planned pirture sequence

AN displays the consistent with schedule status of craft to the Ground Controller.....



### Check 2.5.3: *i*\* Dependencies in UC Descriptions

#### Revealed significant use case description omissions – Task descriptions missing from use cases



### **Synchronisation Check Consequences**

#### Led to model and specification revisions

- More complete use case specifications
- More complete scenarios to walk through in ART-SCENE environment
- More complete requirement statements derived from improved *i*\* SD and SR models (Maiden et al. 2004)
- Demonstrated benefits of context-rich descriptions of current system

Led to wider consideration of time-specific concepts

Event-driven departure management protocols

### **Two Research Challenges Revisited**

#### Our research results can scale

- *i*\* modeling was tractable and useful, with tool support
- ART-SCENE scenario walkthroughs are cost-effective
- But long-term commitment was needed from us!

### Synchronising different models

- Revealed important and new insights into a complex operational specification
- *i*\* models impact on other specification representations
- Human intervention to interpret

Repeat experience - EASM specification

Introduce new collaborative tool to generate candidate issues