

Appendix A

Overview of Data Collection Methods

Research Journal

A research journal is an ongoing chronologic document written by the researcher and containing different types of information. Research journals, as other journals, reflect the perspective of the writer and cited perspectives of other informants. It contains information, which complements data from project journals, descriptions of research setup, methods, and strategies as well as reflections of the researcher on the research project. Research journals require a rather small effort from the researcher as they mainly serve as complementary data source and medium for reflections on the research project. The categorisation and analysis of research journals is expected to require the largest effort for the researcher although this depends on the design, i.e. if the journal is kept formally with a template and possibly in electronic form, or if it is in informal style written into a textbook.

Project Journals

Similar to the research journal project journals are ongoing chronologic documents written by the researcher. They contain project-specific information, i.e. technical details of the system of the project and observations of the (participant) observer. The observation information comprises field notes from the observations in different situations, such as desk, coffee corner, during lunch, and in meetings, and pointers to other data sources such as audio and video records, setups of audio and video recordings. Technical details are related to the participant observers role in the corresponding project. The researcher effort is a bit less than for the research journal as the journal is by definition focused on a single project.

Participant Journals

Participant journals are project journals kept by participants. Depending on the instructions, these journals can have a stringent template and formal character or completely free form providing the largest freedom for the writer. Participant journals require a large effort of the participants. This effort is comparable with

the researcher effort for writing the research journals. This data collection method requires the participants to document what they are doing and represents the exclusive perspective of the journal writer. The researcher effort depends on the allowed freedom of the writers but can be generally compared to the other two aforementioned types of journals.

Audio and Video Records

Audio and video records of observed activities are the least pre-filtered data collection method. The data can be approached and revisited with different perspectives. What is captured by the recorders can be observed with different foci several times as the main restriction on the data is viewpoint. The viewpoint can be a stationary camera, which is not moved or refocused on pre-defined field of view, or it is a mobile camera that is switched on when the observer identifies something interesting during the observation. This option causes already a pre-selection which might constrain the value of the data afterwards or ease the selection of critical situations as the observer's attention has been caught by something happening.

Audio and video records can be performed in regular formal and informal meetings, within offices of participants, and in the coffee corner to get insights into diverse work situations. For a participant observer regular records represent the viewpoint of one member in a team, i.e. only meetings are recorded in which the participant observer is involved. The regular office records are made in the participant observer's office therefore show the interaction of the participant observer and the other participants located in the same office. Writing the minutes of meeting and memos as a service in return increases the acceptance of the recording devices, which are quickly not noticed anymore by the participants in interaction.

Apart from acceptance, audio and video records require no participant effort. Researcher effort is firstly to set access and permission to record. Secondly, the records have to be listened/watched at least two times before selection and more in depth analysis. Transcription of selected excerpts requires significant efforts.

Email Collection

Collected emails provide insights into written interaction between co-located and distributed actors. In addition to the email attachments such as pictures or other documents under discussion are accessible. Only emails, from and addressed to (direct, cc, bcc) the participant observer in his role as thermo-mechanical specialist within the teams are stored.

Email collection does not require additional efforts for the participants and provides an authentic insight into written interaction between participants. With common email exchange tools, which are implemented in standard office, software packages the search and tracking of email interaction can be performed with a small researcher effort.

Documentation Collection

Documentation provides insight into formal documents such as technical drawings, minutes of meetings, requirements specifications, and statement of work. These documents represent what is "frozen into documents" (Ehrlenspiel, 2007). In addition, informal documentation such as hand sketches written on napkins, paper, or whiteboards complement the set of information. Documentation collection does not require an additional effort for the participants as the document creation is part of the observed work activity. Documentation collection requires a higher researcher effort than email collection as the storage structure is mostly less organised and therefore a higher search and structuring approach is necessary.

Interviews

Interviews require a small participant effort, as participants have to spend time to answer questions from the researcher. Researcher effort depends on the structure of the interview. A non-structured interview requires the highest analysis effort for the researcher but leaves the most freedom for the interviewee.

Physical Artefacts

Physical artefacts such as prototypes, test models, and final products provide information on what and how has been realised in the end. This information allows for analysing decided solutions and their implementation. There is no participant effort and the researcher effort is small, mainly the documentation (e.g. pictures) and its accurate localization in time.

Appendix B

Complementary Information on S1

Table 68 List of S1 participants occurring in the analyses

ID	Information	Org.	Officer responsible for	Administrative team
Aik	Electronics engineer; started with ORCA2 and EAGLE2 projects; radiation analyst	L	Power	QAPA expert
Ben	Aerospace engineer, specialisation on ground segment; project manager of EAGLE2	L	Ground segment	Configuration manager of COLIBRI and EAGLE1
Cis	Financial and contractual specialist; started with ORCA2 and EAGLE2 projects	L		Finance and contracts
Fid	Aerospace engineer, specialisation on electro-mechanics; radio amateur	L		QAPA manager
Gab	RF specialist; programme manager, project manager of EAGLE1 and COLIBRI; system architect of ORCA2; radio amateur	L	Payload; launcher segment	
Han	Aerospace engineer, specialisations in thermodynamics, structures and space systems participant observer (author)	L	Structures and mechanisms	
Jan	RF specialist sharing the tasks on the communication subsystem with Pit	L		
Jas	Geographer; Managing director of Company L	L		Director
Jim	Aerospace engineer, specialisation on software and simulation	L	AOCS	
Jon	Aerospace engineer, specialisation on thermodynamics and space systems; ORCA2 project manager	L	Thermal, structures and mechanisms	QAPA expert
Kai	Software and electronics engineer	L	OBDAH	
Lam	Project manager of ORCA1	L		
Pit	RF specialist sharing the tasks on the communication subsystem with Jan; started with EAGLE2 and ORCA2	L	Communications	
EtX1	Employee of electronics subcontractor involved in all five projects	ET		
Orc1	Major contact person of ORCA2 customer organisation	O		
Oth	Other participants such as Ged (data service specialist of Company L), Nun (involved only in ORCA1), Mai (involved only in EAGLE1 and COLIBRI)			

Table 69 Chronology of project EAGLE1 within S1

T_S1	
30	Start of project
88	Start of researcher's involvement in project
284	Environmental tests
361	Design modifications because of electromagnetic issues
374	Design modifications because of launcher interface issues
479	Launch
767-772	Commanded sleep for 4 days of recovering
1158	Used to test ORCA2 ground stations
1389	Still operational

Table 70 Chronology of project COLIBRI within S1

T_S1	
4	Negotiation meeting with customer
37	Kick off
61	Start of work
73	Schedule negotiation
85	Start of researcher's involvement in project and start of detailed design stage
248	Subcontracting integration of filter
302	Design changes on filter and receiver unit L because of different simulation results
326-405	Acceptance tests of filter and receiver units
424-430	Delivery of receiver L and filter to customer and acceptance
438	Computer unit retrieved from space for modifications
466-474	Launch of receiver L, receiver N, and filter unit, waiting for re-launch of computer unit
494-527	Successful long-term tests on ground involving filter and receiver L unit engineering models with the flight model of the computer unit
541	Installation of antenna on ISS
737	Switch on of receiver N
848-858	Exchange of receiver N by receiver L; receiver L not functioning
863	Rebuilt proposal for receiver unit L2
920	Inquiry board
1087	Retrieval of receiver unit L for error investigations
1088	Design modifications for receiver L2
1151	Tests of retrieved receiver L flight model; full functioning according to specifications
1389	Launch and contractual situation for receiver L2 still pending

Table 71 Chronology of project ORCA1 within S1

T_S1	
393	Top-level mission requirements
437	Spacecraft concepts
450	Introduction of concurrent engineering tool by project manager
470	Green light from customer
478	Team internal kick off
516	Second team internal kick off
522	Planned official kick off meeting postponed because of unexpected customer reasons
555	Negotiation meeting
593	Strategic decision to change team composition
599	Kick Off meeting with customer
620	Third team internal kick off
652	Programmatic change also changing constraints on satellite architecture
687	Midterm review; videoconference because of volcano cloud
787	Second midterm review
796	Strategic programme meeting including change of project management
839	Researcher not anymore actively involved in project
991	Final review meeting and closure of project

Table 72 Chronology of project EAGLE2 within S1

T_S1	
479	Concept exploration start
556	"Green light" for concept exploration
641	Kick-off
652	Programmatic change
778	Vibration test of structure subsystem (option 1)
796	Strategic programme meeting
799	Upgrade meeting; free-flyer option (option 2)
836-1138	On hold; currently no launch opportunity because of ORCA2 priority and mass constraints; flat option (option 3)
1138	Distributed flat option (option 4)
1146	Earliest launch opportunity for spacecraft together with ORCA2 second spacecraft expected not before 5 months
1202	Assembly and integration subcontracted to Company A because of ORCA2 priority
1270	In-official launch date shifted to one week earlier
1289	Vibration test of integrated system
1290	Discovery of major errors in assembly and integration
1291	Cancellation of launch opportunity
1292	On hold

Table 73 Chronology of project ORCA2 within S1

T_S1	
557	"Green light" from director to start with concept generation
599	Start of negotiation with customer
600	High level requirements and statement of work iteration meeting of the project team
652	Programmatic change
662	Kick-Off meeting
711	Director: " <i>we have a deal</i> "
796	Strategic programme meeting
830	Go for purchase orders
848	Contract signature
920+921	Preliminary Design Review (telephone conference with customer)
967+968	Critical Design Review, then start of production and deployment stage including assembly, integration and testing of first spacecraft
984	Last spacecraft of customer quits service
1082	Test Readiness Review for first spacecraft
1110	Detailed design of second spacecraft for different launcher
1142+1143	Vibration test of first spacecraft
1146	Earliest launch opportunity for second spacecraft together with EAGLE2 expected not before 5 months
1156	Thermal vacuum test of first spacecraft
1195	Pre-Shipment Review and shipment of first spacecraft to launch base
1228	Launch of first spacecraft
1228-1248	In orbit testing of first spacecraft
1254	Slight adaptations and integration of second spacecraft
1270	In-official launch date for second spacecraft shifted to one week earlier
1277+1278	Vibration test of second satellite; ground station repair
1285	Pre-Shipment Review for second spacecraft
1293	Shipment of second spacecraft
1317	Launch of second spacecraft
1327	Contract closure
1327-1397	Operations and support until project closure

Appendix C

Complementary Information on S2

Table 74 Study participants within S2

ID	Information	Org	Workplace	Responsibility
Mod	An engineer from the CEF core team, team leader and moderator role for the first time	D1	Moderator	Moderator
Sci1	A solar physicist from the scientific team who is continuously in the design session and responsible for the final mission proposal (as principal investigator); first time working in a concurrent design facility	M	System	Science and System
Sci2	A solar physicist from the scientific team who is participating from the first day to the afternoon of the third day; with a background in solar science instruments; first time working in a concurrent design facility	M	Science	Science
Sci3	A solar physicist from the scientific team who is participating during the second day; first time working in a concurrent design facility	M	Science	Science
Sci4	A solar physicist from the scientific team who is participating during the third and fourth day; first time working in a concurrent design facility	M	Science	Science
Mis	An engineer from the CEF core team	D1	Mission	Mission Analysis
Cos1	An engineer with degrees in electronics and finance	D2	Cost	Cost
Cos2	An engineer with degrees in technology management; supporting Cos1	D1	Cost	Cost
Str1	A student doing an internship within the department	D1	Structure	Structure
Str2	An engineer who graduated approximately one year ago in this organisation (Company D)	D1	Configuration	Configuration
Str3	Student performing graduation thesis within the department; supporting Str1 and Str2	D1	Configuration	Configuration
Thr	An engineer specialised on thermodynamics		Thermal	Thermal
Pwr	An engineer from the CEF core team who worked as configuration officer within CEF1 but here as power officer; joined the session on the second day	D1	Power	Power
Aoc	An engineer with focus on guidance, navigation and attitude control	D3	AOCS	Attitude and Orbit Control Subsystem
Prp	Bachelor student performing graduation thesis within the department	D1	Propulsion	Propulsion
Com	An engineer from the CEF core team who is normally doing the moderator role	D1	Communication	Communication and Ground System
Dat	Student performing internship within the department; first time working in a concurrent design facility	D4	Data handling	Data Handling Subsystem (DHS)
Oth	Other participants such as the head of department D1; visitors from other departments with interest in software issues; observers from DICA lab of University of Luxembourg			

Appendix D

Basic Information on Themes

Table 75 Basic information on theme Interproject

Theme	Interproject
Number of key events	29 (etic link)
Duration of theme	1037 days
Participants (appearing in the analysis)	EngS, AdminS, and CustS participants
Involved organisations and their roles	<ul style="list-style-type: none"> o Company L involved in different roles in all projects, as contractor and customer in EAGLE1 and EAGLE2, as subcontractor in COLIBRI, and as contractor in ORCA1 and ORCA2; o Company O as customer of ORCA2; o Company ET as subcontractor of EAGLE1, COLIBRI, EAGLE2, ORCA2; o Company ES as customer of COLIBRI and ORCA1;
Projects and project stages	5 projects (EAGLE1, COLIBRI, EAGLE2, ORCA1, ORCA2) several project stages EAGLE1, COLIBRI, ORCA2 from concept exploration to operations and support, ORCA1 only concept exploration, EAGLE2 concept exploration to production and deployment.
Data	Emails, documents (e.g. lessons learned; ORCA2 statement of work, high level requirements), audio and video records of meetings, informal conversations with project manager of EAGLE2 and QAPA manager of Company L.
Level of analysis	Macro

Table 76 Basic information on theme Harness

Theme	Harness
Number of key events	3 (etic link)
Duration of theme	20 days
Participants (appearing in the analysis)	EngS team members Pit, Han, Jon, Jim, Gab, and Kai (all Company L staff), SubcoS team member (of Company G)
Involved organisations and their roles	<ul style="list-style-type: none"> o Company L involved in different roles in all projects, as contractor and customer in EAGLE1 and EAGLE2, as subcontractor in COLIBRI, and as contractor in ORCA1 and ORCA2; o Company G, involved as subcontractor for the harness manufacturing of ORCA2
Projects and project stages	1 project (ORCA2) in the detailed design stage
Data	Research journal, project journals, audio records of office talk, audio and video records of team meetings in ORCA2
Level of analysis	Macro, meso (for d901 and d920)

Table 77 Basic information on theme Li-ion cells

Theme	Li-ion cells
Number of key events	3 (etic and emic links)
Duration of theme	500 days
Participants (appearing in the analysis)	EngS team members Aik, Jon, and Gab; AdminS team member Cib (all Company L staff)
Involved organisations and their roles	Company L involved in different roles in all projects, as contractor in ORCA2;
Projects and project stages	1 project (ORCA2) in the detailed design stage
Data	Research journal, project journal, documentation, audio and video records of team meetings in ORCA2
Level of analysis	Macro

Table 78 Basic information on theme EMC & mechanics

Theme	EMC & mechanics
Number of key events	4 (etic and emic links)
Duration of theme	904 days
Participants (appearing in the analysis)	EngS team members Han, Jon, Pit and Gab; AdminS team member Fid (all Company L staff)
Involved organisations and their roles	Company L involved in different roles in all projects, as contractor in ORCA2
Projects and project stages	3 projects: P3E (a small project of Han and Fid exploring concepts for electronics boxes) parallel to involvement in COLIBRI detailed development; and ORCA2 detailed development
Data	Research journal, project journal, documentation (change-log of CAD data), emails, physical artefacts audio records office work;
Level of analysis	Macro

Table 79 Basic information on theme EMC & power

Theme	EMC & power
Number of key events	5 (etic and emic links)
Duration of theme	638 days
Participants (appearing in the analysis)	EngS team members Han, Jon, Pit and Gab; AdminS team member Fid (all Company L staff); two different SubcoS team members
Involved organisations and their roles	<ul style="list-style-type: none"> o Company L involved in different roles in all projects, as contractor in ORCA2; o Company J as customer in another project but mainly as discussing partner on a problem that occurred in Company L and J o Company ET, as subcontractor involved in all three relevant projects experiencing the problem together with Company L o Company C, a subcontractor for the power subsystem being warned on an issue by Company L
Projects and project stages	3 projects: EAGLE1 in the testing stage, EAGLE2 in the conceptual design stage and ORCA2 in the detailed development stage
Data	Research journal, project journal, documentation; emails; audio records of office work and meetings
Level of analysis	Macro

Table 80 Basic information on theme Sun sensor

Theme	Sun sensor
Number of key events	2 (emic link)
Duration of theme	12 days
Participants (appearing in the analysis)	EngS team members Han, Jon, Jim and Gab;
Involved organisations and their roles	Company L involved in different roles in all projects, as contractor in ORCA2
Projects and project stages	1 project: ORCA2 in operations and support of first spacecraft
Data	Research journal, project journal, documentation; emails; audio records of office work and meetings
Level of analysis	Macro

Table 81 Basic information on theme Accommodation

Theme	Accommodation
Number of key events	2 (emic link)
Duration of theme	352 days
Participants (appearing in the analysis)	EngS team members Han, Jon; SubcoS team member etx1
Involved organisations and their roles	<ul style="list-style-type: none"> o Company L involved in different roles in all projects, as contractor in ORCA2; o Company ET, as subcontractor involved in all three relevant projects experiencing the problem together with Company L
Projects and project stages	2 projects: COLIBRI assembly stage (within production and deployment) and EAGLE2 conceptual design
Data	Research journal, project journal, documentation; emails; audio records of a meeting
Level of analysis	Macro

Table 82 Basic information on theme Stiffness

Theme	Stiffness
Number of key events	5 (etic and emic links)
Duration of theme	124 days
Participants (appearing in the analysis)	EngS team members Gab, Han, Jon, Jim
Involved organisations and their roles	Company L involved in different roles in all projects, as contractor and customer in EAGLE1 and EAGLE2, as subcontractor in COLIBRI, and as contractor in ORCA1 and ORCA2
Projects and project stages	2 projects: EAGLE2 in production and deployment stage; ORCA2 in detailed design stage
Data	Research journal, project journals, audio and video records of office talk
Level of analysis	Macro; meso (for d892 and d899)

Table 83 Basic information on theme Radio

Theme	Radio
Number of key events	29 (etic link)
Duration of theme	964 days
Participants (appearing in the analysis)	EngS team members Pit, Han, Jon, Jim, Gab, Ben, and Jan (all Company L staff)
Involved organisations and their roles	Company L involved in different roles in all projects, as contractor and customer in EAGLE1 and EAGLE2, as subcontractor in COLIBRI, and as contractor in ORCA1 and ORCA2
Projects and project stages	3 projects (EAGLE1, EAGLE2, ORCA2) from concept exploration to production and deployment
Data	research journal, project journals, audio records of office talk, audio and video records of EAGLE2 and ORCA2 team meetings
Level of analysis	Macro; meso for d794

Table 84 Basic information on theme AOCS-fuel

Theme	AOCS-fuel
Number of key events	10 (etic link)
Duration of theme	3 days
Participants (appearing in the analysis)	CengS team members Aoc, Mod, Mis, Str1, Str2, Str3, Pwr (Company D staff); SciS team members Sci1, Sci2, Sci3 (Company M staff)
Involved organisations and their roles	<ul style="list-style-type: none"> o Company D (same institutional organisation as in PS2 (CEF1 project) but partially different participants as in PS2, acting as contractor) o Company M (institutional organisation as customer) o Company ES (addressee of proposal, sponsoring organisation)
Projects and project stages	1 project: CEFX in concept exploration stage (preparation of project proposal)
Data	Research journal, project journals, audio and video records within S2 + interviews of participants performed during and after the study
Level of analysis	Macro, meso (for d2_1154), micro (for d2_1149)

Table 85 Basic information on theme Occulter

Theme	Occulter
Number of key events	17 (etic and emic links)
Duration of theme	3 days
Participants (appearing in the analysis)	Aoc, Mis, Mod, Sci1, Sci2, Sci3, Str1, Str2, Str3, Pwr
Involved organisations and their roles	<ul style="list-style-type: none"> o Company D (same institutional organisation as in PS2 (CEF1 project) but partially different participants as in PS2, acting as contractor) o Company M (institutional organisation as customer) o Company ES (institutional organisation acting as envisaged sponsoring organisation)
Projects and project stages	1 project: CEFX in concept exploration stage (preparation of project proposal)
Data	Diverse excerpts of video-records and interviews from S2
Level of analysis	Macro