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Quantitative Methods for Analysing Joint Questionnaire Data: Exploring the Role of Joint in Force Design

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ABSTRACT

In 2012 and 2013, the Joint and Operations Analysis Division conducted a survey data collection activity with the aim of exploring the role of Joint in Force Design.

The study postulated that 'Joint', is a complex and abstract concept at best, and can be represented conceptually by a three dimensional space comprising: Coordination and Organisation; Social Capital; and Optimisation of the Socio-technical Systems. Given the variability of the joint activities selected by respondents, and the small sample size, quantitative analysis was conducted on the collected data. This statistical analysis and visualisation helped triangulate the study's findings, and provided a measure of confidence in the respondent's complex, multi-faceted joint responses.

The analyses included Chi-Squared, Hierarchical and K-Means Cluster, Exploratory and Confirmatory Factor Analysis, and Generalised Least Squares. Three-dimensional cube visualisation and weighted two-dimensional representations of a group's measure of 'Jointness' were produced. These were used to relate participants views held on aspects of capital, coordination, and socio-technical systems.

This document will discuss the specific methods used and the insights gained as a result.

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Executive Summary

In 2012 and 2013, the Joint and Operations Analysis Division conducted a survey data collection activity with the aim of exploring the role of Joint in Force Design. The study was postulating that 'Joint' can be represented conceptually by a three dimensional space comprising: Coordination and Organisation; Social Capital; and Optimisation of the Socio-technical Systems.

Joint is a complex and abstract concept at best, and so the study had two key challenges. One was to develop a survey instrument to investigate the alignment of organisational entities to joint tasks as seen by the head of each organisational entity. The second challenge was to map the complexity of the concept of Joint through the lens of each respondent. Because of the variability, and the small sample size, quantitative analysis was conducted to build a measure of confidence into the complex, multi-faceted joint responses.

The analyses included Chi-Squared, Hierarchical and K-Means Cluster, Exploratory and Confirmatory Factor Analysis, and Generalised Least Squares. Three-dimensional cube visualisation and weighted two-dimensional representations of a group's measure of 'Jointness' were produced.

Confirmatory Factor Analysis highlighted the value and contribution that informal links play over formal links, and the tendency for *Joint* staff to answer questions in the higher end of the bipolar scales, suggesting that people within these groups are reasonably aligned in the Australian Defence Organisation. A key observation is that the approach of analysing multi-faceted concepts of 'Joint', where a respondent can choose to answer their questions through their own lens, is a successful approach.

The analysis found that 'Joint' can be represented conceptually by a three dimensional space comprising: Coordination and Organisation; Social Capital; and Optimisation of the Socio-technical Systems, and it became clear that there are similarities between the theoretical and observed constructs on how 'Joint' was represented. The analysis provided a measure of confidence to the survey data and demonstrated the value of the wider aspects of the survey analysis.

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Acronyms

Acronym	Meaning
ADF	Australian Defence Force
ADO	Australian Defence Organisation
AMOS	Analysis of Movement Structures
C&O	Coordination and Organisation
CFA	Confirmatory Factor Analysis
EFA	Exploratory Factor Analysis
GLS	Generalized Least Squares
HAC	Hierarchical Cluster Analysis
JCCC	Joint Capability Coordination Committee
JOAD	Joint Operations & Analysis Division
JOD	Joint Operations Division
LMO	Kaiser-Meyer-Olkin
LV	Latent Variable
OSTS	Optimisation of Socio-technical Systems
PCA	principal component analysis
QUAID	Question Understanding Aide
SART	Situational Awareness Rating Technique
SEM	Structural Equation Modelling
SPSS	Statistical Package for the Social Sciences

1. Introduction

Defence doctrine defines joint as "activities, operations and organisations in which elements of at least two Services participate [1]", and the last 25 years have seen the ADF become proficient in the conduct of joint operations. However, the ability to master future joint operations will require 'jointery' to be extended to force design and capability management within the wider Australian Defence Organisation (ADO).

The drivers for joint include the increasing need for greater efficiency; the desire for finer control over the application of lethal force; and the requirement for the military to be employed in an ever increasing range of missions. In this complex environment any force that can work together more effectively than its opponent will have a significant advantage. A joint approach involving the creation of new capabilities through the synergistic use of separate Service capabilities provides Government with increased flexibility and a more agile Defence capability.

In 2012 JOAD (then Joint Operations Division (JOD)) initiated the Joint Study to help Defence better understand the Australian approach to joint. The Joint Study has explored the concept of joint, the evolution of joint within Australia and how joint applies to command of operations, management of the current force, and design of the future force. An important component of the Joint Study, known as the Joint Space Analysis, has involved an investigation of Defence organisational entities and their alignment to joint activities."

2. Joint Space Analysis

The detail of how individual commands and branches in Defence contribute to joint tasks is not so well understood. Joint constitutes an operating space of sorts, within which organisational entities, or ADO branches, conduct activities. These range from being tactical and 'proximal' to operations or concerned with their planning ahead of time, or more distally related still, concerned with designing and developing the future force. The approach to exploring Joint in the ADO was to analyse the ability of ADO entities (i.e. branches) to undertake Joint activities, in other words its alignment to Joint.

There were a number of stages conducted before a preliminary study commenced. A literature review was conducted and the properties of 'Joint' were explored from a diverse range of disciplines that included organisational design, organisational psychology, sociology, human factors, command and control, systems analysis, mathematics and engineering. A theoretical or conceptual model of 'Joint' was developed based on three Latent Variables (LVs) or constructs that aligned with the cross-disciplines. They were: *Coordination and Organisation* (organisational design, command and control theory), *Social Capital* (human factors, organisational psychology, sociology), and *Optimisation of Socio-technical Systems (OSTS)* (systems analysis, human factors, mathematics and engineering).

A literature review identified three bodies of knowledge. They were: command and control and organisational sciences; organisational psychology and behavioural psychology disciplines; and systems sciences and network centric warfare. From these, three conceptual constructs for Joint were established. They are highlighted with a definition as follows: Coordination and Organisation (C&O). *The balance between specialisation to achieve organisational mission versus the need to invest in coordination in order to collaborate with other organisations*; Optimisation of Socio Technical Systems (OSTS). *The integration of technology within the human centric systems and the associated emergent properties at the Joint system level*; Social Capital. *The collective capacity to draw on previous experience and networks to achieve joint outcomes*.

The study postulated that it is possible to represent organisational entities, or Defence branches, in a three-dimensional space defined by the joint space dimensions. A conceptual model of joint was developed which allowed each of the multidimensional joint constructs to be reduced to a single dimension. Branch results from the survey are represented visually as points in a cube using the joint space dimension described above. The position of the entity within the joint space reflects the level of the entities alignment with Joint, and the ability to undertake or contribute to Joint activities. Objective data on each entity was obtained independently of the survey (e.g. size, geographic and hierarchical location, staff composition, longevity, role, etc.). This was later used as a filter to aid analysis of survey results within the joint space construct.

It is possible to create an analogous *Single Service* (SS) cube representation for the same organisational entities. The difference between the SS and Joint cube representations should be a measure of the relative preference for SS or Joint activities. The null hypothesis is that there is no significant difference between Joint and single Service cube representations for each branch.

2.1 Key Findings

The joint space results show five clusters, the positions of which are generally invariant to clustering technique, survey weighting, and type of task, be it single service or Joint. That is, the cluster positions and role appears consistent even though the cluster membership changes significantly with Joint or SS task cubes.

The clusters represent modes of interaction or alignment with Joint, or SS, and these can be described in terms of commonalities of branches within each cluster. This characterisation allows us to talk in terms of leading, supporting, specialist capability management, contributing, disconnected and isolated from Joint/SS. These are the modes in which the branches can exist. It is possible that additional modes might have been identified if all Defence branches were sampled.

The cube diagram on the left of Figure 1 shows an example of a clustering of survey results – in this case the J4 cluster – with the red square being the mean of the points in the cluster. The cube diagram on the right shows the mean for the five clusters identified in this analysis.

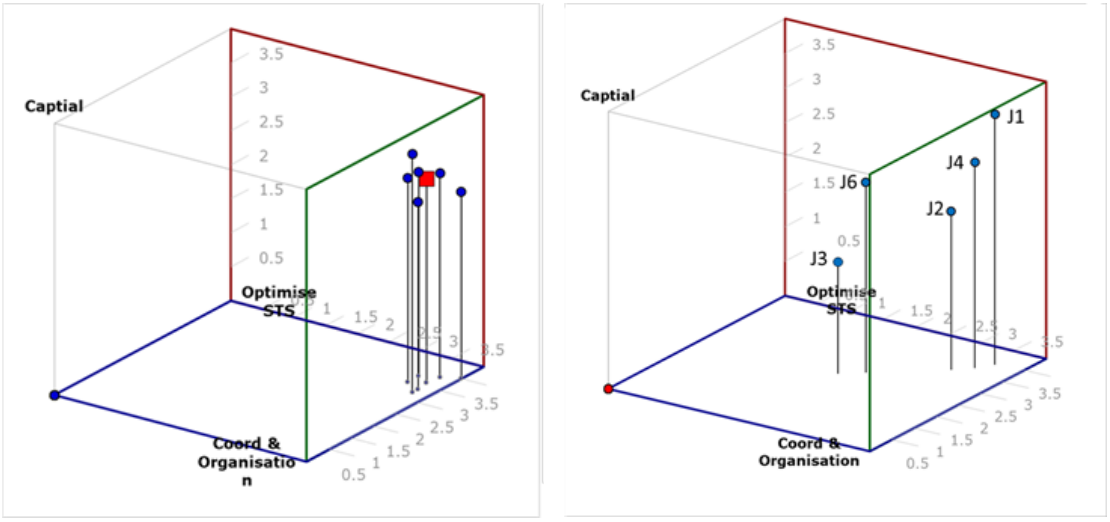

Figure 1 Example of cluster diagrams

The objective of the clustering was to describe a conceptual model against the way the ADF does joint activities. The clustering identified that within the joint cube data there were 5 clusters, the cluster positions and roles appear consistent even though the cluster membership changes with task. The clusters represent modes of interaction/alignment and can be described in terms of commonalities of branches within each cluster (see Table 1).

The position of the cluster centroid is similar for SS and J cubes though cluster composition changes. We argue that the clusters are representative of alignment with cube type (J or SS) and that this reflects underlying structure, i.e. modes of interaction with Joint.

Table 1: Cluster details

Cluster	Label	Description
C1	Leaders	Cluster is highly joint and comprises branches that lead joint, specifically for operations. This cluster can be seen as champions of joint, driving joint tasks, organisations and capabilities.
C2	Specialist Joint	Cluster manages or supports specialist joint capabilities (e.g. Information, Surveillance and Reconnaisance). Branches in this cluster are proficient at joint but with a narrow focus that aligns with strong single service drivers.
C3	Disconnected	Cluster sits on the periphery of joint and comprises branches with little serious requirement for joint beyond 'common' enterprise jointness.
C4	Supporters	Cluster comprises branches that are heavily focussed on supporting joint activities or capabilities.
C5	Contributots	Cluster comprises branches who may be called upon to contribute to joint but are generally single service focussed.

Understanding where branches sit and where they should sit is a useful means of exploring the effectiveness of the principal joint functions and the alignment of the ADO branches to these functions. This can assist with identifying the means of intervention.

It was found there is a high level of background or 'common' Joint in the ADO.

A comparative analysis of Combined (US-AUS) and Joint cubes was conducted in order to explore the relative alignment of the organisational entities to Joint and Combined activities. Results showed the Services are more aligned to Joint than Combined, although for Navy there is not a lot of difference between Joint and Combined. However, at no stage is a Service more aligned to Combined than Joint on any axis construct.

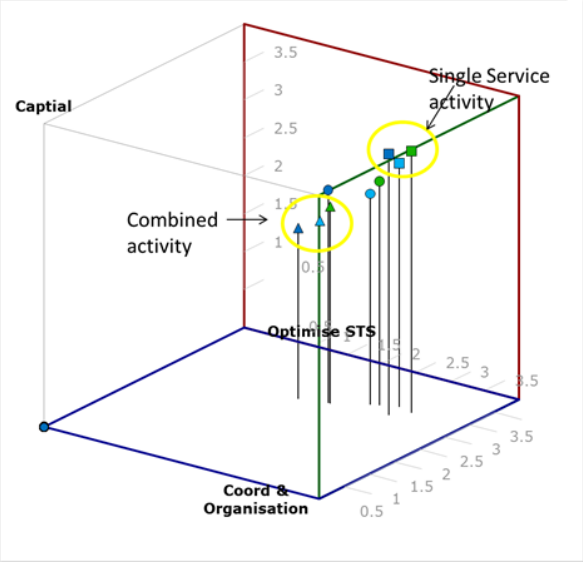

Figure 2 Combined cluster diagram

The cube diagram (Figure 2) highlights the analysis of the Combined 'cube' data. The main result shows the Navy, Army and Air Force centroids, or the mean of all the branch results for a given Service, for Combined, Joint and Singe Service activities. Blue = Navy, Green = Army and Light Blue = Air Force. Square = SS activity, or the response to SS questions, circle = Joint activity, and triangle = Combined activity.

The joint study has shown that the most important component is joint capital. The approach to Joint is influenced by a Service's understanding (e.g. Army, Navy, Air Force) of, and experience with, operating jointly, that is, what it draws from Joint and the degree to which it requires Joint.

2.2 Limitations

There were a number of limitations in the study. They were: The large variation in the types of tasks that branches conduct and the possibility that the respondents did not sufficiently cover all principal joint functions; The small sample size of branches limited the level of statistical analysis conducted, and there were concerns about samples being right, or using enough branches; That the survey respondents had provided branch information without bias; and, the possible introduction of instrument artefacts due to survey ambiguity.

Joint is a complex and abstract concept at best. Given the variability of the joint activities selected by respondents answered through their perception of 'Joint', and the small sample size, quantitative analysis was conducted on the collected data. This

statistical analysis and visualisation provided a measure of confidence in the respondent's complex, multi-faceted Joint responses.

Given this complex nature of Joint concepts, the objective of the statistical analysis was to understand and to build confidence in the results to support the wider study and the development of the future joint force.

3. Survey Design and Preparation

A study was conducted during 2012/2013 to determine how 1 Star and Senior Executive Service (SES) Band 1 personnel perceived the relevance of their branch alignment, which included Commands, Formations, Force Element Groups, and Branches, to joint activities. The aim of the study was to investigate how the concept of Joint contributes to the development of the future joint force. A survey instrument was developed to measure the dimensions of the Joint space discussed in Section 2.

The study team conducted a workshop that took the insights of the literature review and developed a question list which was linked to the three constructs. This resulted in those constructs being represented by approximately eight questions each (25 questions were developed in total). The challenge was to reduce or consolidate these to a measurable and manageable set against which it would be possible to collect the data. A 14 question survey instrument was developed, and the Situational Awareness Rating Technique (SART) informed the development of the first 9 questions.

The survey instrument was a modification of the Situational Awareness Rating Technique (SART) [2 3 4], a ten question survey aimed to capture an individual's instantaneous situational awareness (SA). Rather than asking questions about an individual's situational awareness (SA), the SART-like questions asked about a branch's awareness of *Joint, Single Service*, and *Combined* activities It allowed the simplification of the 25 master question list into the 14 final survey questions that were given equal weighting. The last four questions provide an opportunity to better understand and expand on group and organisational concepts.

Professor Paul Salmon from the University of the Sunshine Coast, a developer of the distributed situation awareness model [5 6], reviewed the survey and assisted in translating the individualistic nature of the questions into the joint branch/organisation structure. Due to the complexity of 'Joint', information was gathered using more than one established method. For instance, the ability of branches to form a network of interactions both within and external to their Service or Group had been identified as a possible determinant of 'Joint'. As such the creation of a series of questions to allow for social network analysis of the formal and informal interactions, and the links between branches. Finally, a number of alignment questions were determined for the purpose of comparing a branch's perceived level of direction, cooperation, and focus. Where possible, non-value-laden, objective questions were selected into a master question list.

A decision was made to sample the ADO at the Branch/Command/FEG level by approaching the relevant 1 Star/SES-1. The decision to sample at this level was influenced by two factors: 1 Star level entities map easily to the Defence Portfolio Budget Statement and across the key areas of the Defence Business Model (Enablers, Capability Managers and Capability Integrators); and collecting data at the branch level is both manageable in size and statistically relevant, while avoiding role duplication which might be evident at lower levels of the defence hierarchy. In essence, the questionnaire seeks 1 Star/SES-1 responses representative of the branch, rather than the individual.

The survey seeks to gain a view of a branch's approach to Joint by examining how the branch conducts a Joint activity and compares that response with identical questions about a *Single Service* activity and a *Combined* (AUS-US) activity. Comparison of the Joint and *Single Service* responses should allow us to identify the degree to which being effective at one impacts on the effectiveness at the other. The comparison with a combined activity was also included because there is anecdotal evidence that some in the ADF see a conflict in being effectively Joint on the one hand and developing interoperability with the US on the other.

A considered assignment, or determination, was made on which branches to include on the sample to get the right contribution of *Joint*, *Single Service*, and *Combined* representation. Of the approximate 200 Defence branches listed in the Defence Portfolio Budget Statements [7], 100 were selected for the study on the basis of the following: cross enterprise-wide representation; relevance to joint activities/entities. The survey sponsor endorsed a sample size of 100, and the branches were chosen.

The survey was validated through an initial pilot study of 20 personnel and was conducted at DSTO. In lieu of using the software tool, QUAID [8], two one star officers, subject matter experts from the Vice Chief of the Defence Force (VCDF) Group's Joint Capability Coordination Division and a one star officer from the Joint Operation Command, were engaged to review the survey and clear up any misunderstanding. They provided peer group context and clarity. During the pilot study, the questionnaire was filled out one on one, not as a group, so that the survey design team could provide feedback and learn about any shortfalls.

The survey was then conducted in two stages: stage one surveyed the Joint Capability Coordination Committee (JCCC), while stage two, the full survey, surveyed the remaining 75 participants from the target group. Initially, in late 2012, the questionnaire was sent to members of the JCCC, a key forum for coordinating joint capability across the ADO, and the results were consolidated. Basic preliminary analysis was conducted of the joint space using Hierarchical and K-Means non – hierarchical Clustering, and three-dimensional cube visualisation of participant's LVs, to ensure that the survey was sound. In early 2013 the second stage of questionnaires were administered to the remaining respondents.

Of the 100 questionnaires administered through both stages, there were 68 respondents. While approximately 70% of the sample population responded, this accounted for approximately 35% of the total population, and it was deemed as a reasonable representation of the small group. This was greater than the typical 10%

survey sample size used to ensure statistical significance [9], and while a sample of 68 was seen to be a small sample size, it was always understood that the survey would never achieve the ideal sample size.

Joint is a complex, multi-faceted concept that can apply to organisations, activities, and capabilities across the tactical, operational, and strategic levels of warfare. The survey targeted groups from across these diverse environments to adequately represent this complex and multi-faceted nature. An attempt was made to capture all these niche areas, and the sample was larger to balance the correct mix of *Joint* and *Single Service* responses. However, this diversity resulted in considerable variability with regards to the way respondents could perceive and answer their questions when they drew on their group's specialised niche capabilities (chosen by Question 1 of Appendix A, Table 4. Study constraints meant that the joint survey could only be conducted once. It was also acknowledged that the relatively small sample size would limit the power of the statistical tests, and could lead to a type II error and fail to identify an association where one actually existed [10].

4. Questionnaire Structure

There were 14 questions in the survey that asked participants to answer how they believed their Branch responded on a number of key areas. These were categorised as questions from a *Joint* perspective, and a *Single Service* perspective. These 14 questions were divided up into three sections. Part one contained a single question that identified *Joint* and *Single Service* activity data that the participant's branch would likely undertake, and this provided context for the next part. Part two comprised a modified set of nine questions, each with a required *Single Service* focussed component and a *Joint* focussed component, as can be seen below in Appendix A, Table 7. Each of these questions used a 5 scale Likert structure to measure the strength of the view held. Part three contained four questions and was a mix of the 5 scale Likert and free text area where respondents provided data that was used to conduct network analysis.

These complex, multi-faceted responses were captured through the specific lens of their ADO branch head. The survey sampled respondents that were across many diverse areas of Joint in an endeavour to ensure it captured this diversity and complexity as best as it could. Initially, of the 14 questions, only the nine from section two that covered the three constructs or latent variables (LVs), of *Coordination and Organisation*, *Social Capital*, and *Optimisation of Socio-Technical Systems (OSTS)* and they are considered in section 5.1 Phase One analysis.

Table 2: Latent Variables - 9 questions

Latent Variable / Construct	Questions
LV1: Capital	7, 8, 9
LV2: OSTS	1, 2, 6
LV3: Coordination	3, 4, 5

The remaining data for the social network analysis provided an opportunity to better understand and expand on group and organisational concepts, and these alignment questions were used later, and are discussed in section 5.2 Phase Two Analysis that used 12 questions (refer to survey questions in Appendix A).

Table 3: Latent Variables - 12 questions

Latent Variable / Construct	Questions
LV1: Capital	7, 9, 11, 12
LV2: OSTS	1, 3, 5, 8
LV3: Coordination	2, 4, 6, 10

The survey had two key challenges. One was using an individual's response to represent a group and organisational environment, and the other was the complexity of the concept of Joint seen through the lens of each respondent.

5. Analysis

There were two phases of analysis conducted on the survey data. What follows is a brief description of the approach that was taken.

5.1 Analytical Analysis Approach

The approach taken in this analysis is to initially examine the questions using K-Means non-hierarchical cluster analysis and determine the optimum number of clusters that are visible within the data. Next, higher level hierarchical clustering is conducted to further explore the clusters in dendrograms and 3-dimensional cube plots using the cluster size previously determined.

Exploratory Factor Analysis is then conducted to identify any underlying structure to the data, and if successful, Confirmatory Factor Analysis is conducted to confirm the robustness of that mode.

In the case of this analysis, Structural Equation Modelling is further conducted to see if observational errors can be removed from the latent variables modelled, and as a final test, chi-square analysis is used to examine the fit of the data and explain several anomalies that are discovered.

5.2 Phase One Analysis

In phase one, initial analysis was conducted on the nine questions. The Statistical Package for the Social Sciences (SPSS) [11] was used to conduct statistical analysis on the sample. Two types of cluster analysis, Hierarchical, and K-Means non-hierarchical cluster analysis were conducted on the data as methods for initial analysis. Three-dimensional scatter plots were also produced for each of the LVs.

Cluster analysis has the advantage of being exploratory, and is an effective tool for clustering unknown groups by maximising dissimilarity and organising data by

various combinations of the independent variables without any preconceived notions [12].

Initially, K-Means non-hierarchical cluster analysis was conducted. This analysis requires the number of clusters determined up front and it attempts to force cases into similar groups [13]. K-Means analysis was conducted with K set between 3 and 6 with a focus on group membership. Eventually, the ideal number of clusters was determined to be between 3 and 4.

Hierarchical Cluster Analysis (HAC) was also conducted on both *Joint*, and *Single Service* responses. HAC attempts to assign the data to clusters based on similarities between distances of similar groups of cases [14]. Dendrograms[1], or hierarchical tree diagrams, were also produced to highlight these clusters.

Three dimensional scatter plots were also produced for each of the three LVs both for *Joint*, and *Single Service* responses in an attempt to visualise the group cluster membership. The results of each participant's views for each of the three latent variables were averaged, and the three constructs or LV's scores were plotted on each of the axis of a 3D scatter/dot plot.

The phase one analysis was encouraging, but it found that there were gaps in the conceptual model fidelity and with the translation of the abstract concepts, and so the constructs were further refined. There was a requirement to better define the three constructs, and the survey instrument was reviewed to see if it addressed the refined constructs. Additional questions that should have been asked were considered.

Noting that there were no further opportunities to re-survey any of the participants, the challenge was in bringing the additional questions from part three of the survey into a structure that augmented the other questions. In refining the model, ways to better use the existing question data were considered to assign them to the constructs. Therefore, analysis was conducted to determine if the gap could be plugged with information from other questions.

Data outside of the initial nine questions was added so that 12 questions fed the LVs. Some of this data was non-Likert, and an independent scale was applied to them, in particular question 10. It was acknowledged that this was less than ideal. The theoretical or conceptual model was refined with the addition of three new questions so that each of the three constructs now had four questions, and a total of 12 questions fed the model.

The data was consolidated for *Joint* and *Single Service* and further statistical analysis and 3-Dimensional cube visualisation occurred, along with some higher fidelity analysis, which suggested that some questions do not add much to the survey.

[1] "A dendrogram is a branching diagram that represents the relationships of similarity among a group of entities." http://wheatoncollege.edu/lexomics/files/2012/08/How-to-Read-a-Dendrogram-Web-Ready.pdf

5.3 Phase Two Analysis

More detailed, higher fidelity analysis was conducted on the refined LVs, or constructs.

SPSS was again used to conduct statistical analysis on the sample. This time factor analysis was conducted. Factor analysis attempts to identify closely related individual items, basic underlying factors, theoretical concepts or constructs. "*It reverses the usual thinking for developing theoretical frameworks and operational values where we are trying to generate numerous items that measure a particular value*" [15].

There are two types of factor analysis, *Exploratory Factor Analysis* (EFA) and *Confirmatory Factor Analysis* (CFA). EFA like its name suggests is exploratory, and attempts to identify the underlying structure or factors in a model, whereas CFA attempts to confirm the robustness of that model [16]. The focus in both cases is on explaining the pattern of correlations between variables, and identifying factors (dimensions) underlying those variables [17].

SPSS has an EFA application called principal component analysis (PCA), and is useful at seeing what items 'hang together' in a questionnaire. Factor items are the correlations between the factor and the item, or the individual question, and by convention must be at least 0.30, but to be unambiguous should be 0.60 or greater. Anything between 0.40 and 0.60 is considered moderate and below 0.40 weak [18].

PCA was conducted on the sample of 68 with a factor loading threshold set to 0.30. Two tests were conducted. The first was to test the responses to the 12 *Joint* questions, and the second was to test the responses to the 12 *Single Service* questions. In both cases the tests were to see how the factors compared with the theoretical model and how they supported the three *Capital*, *Coordination*, and *OSTS* constructs.

One of the assumptions with PCA is to have a large ratio of N/variables of usually at least 5:1, preferably 10:1 [19]. There were 12 questions that were examined against the three theoretical latent variables, or factors. Testing a model with 12 values means there should have been a sample size of at least 60, but preferably 120. In this instance a sample size of 68 was sufficient to meet the minimum requirements.

The results for the *Joint* and *Single Service* analysis were encouraging. In both cases, the correlation matrix highlighted a number of correlations visible to the eye. Correlation matrix determinants were close to 0, (0.026 for *Joint* and 0.001 for *Single Service*) and indicates a good fit of the data in these results. This indicates there may be an opportunity to use Confirmatory Factor Analysis to test the hypotheses [20].

The Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy was greater than 0.5 for *Joint* (0.702) and *Single Service* (0.867), and close to a score of 1, highlighting a satisfactory sampling adequacy. Bartlett's test was less than 0.05 ($p < 0.001$) and significant in both cases, highlighting the variables (questions) do have some correlation to each other.

The Chi-Square results suggested a good fit to the data, although the *Single Service* results (418) is higher than the *Joint* (226.3), which suggests the data is more normal than the *Joint* results. Given the role and responsibility profile of the Navy, Army and

Air Force it is not surprising that *Single Service* results were more normal and further suggested that *Joint* is considerably different to the *Single Services*.

Factor Analysis identified four underlying factors within the data for *Joint*, with the first factor accounting for 30.4% of the total variance in the data (the second, 12.6%, third, 11.1%, and fourth, 10.3%), and contributed a total of 64.4% of the total variance. Three factors were extracted for *Single Service* (first factor, 44.8%, second, 12.2%, and third, 8.7%), with a total contribution of 65.7% of the total variance. The remaining factors controlled only small amounts of variance and were not significant but between them accounted for the remaining 35.6% (*Joint*), and 34.3% (*Single Service*).

The results of the analysis of the Rotated Component Matrix, (refer Table 4), highlighted some commonality between the questions from the theoretical constructs and those identified within the four factors. Six of the twelve *Joint* questions were correctly identified to the constructs, as were eight of the *Single Service* questions (highlighted in yellow). Another *Single Service* pair, (Q6-Q10 highlighted in blue), while not separated on their own factor they were also common.

Table 4 EFA comparison

Factor	**1**		**2**		**3**		**4**	
Service Type	Joint	Single Service	Joint	Single Service	Joint	Single Service	Joint	Single Service
LV1: Capital	Q7	Q7	Q9	Q9	Q11	Q11	Q12	Q12
LV2: OSTS	Q1	Q1	Q3	Q3	Q5	Q5	Q8	Q8
LV3: Coordination	Q2	Q2	Q4	Q4	Q6	Q6	Q10	Q10

Given these encouraging results, it was appropriate to examine these factors further through Confirmatory Factor Analysis (CFA) using an advanced Structural Equation Modelling software package called Analysis of Movement Structures (AMOS), a plug-in for SPSS that does CFA, and aims to examine the robustness of an EFA model [21 22].

Each of the three Single Service and Joint LV's were modelled within AMOS, and the CFA results were promising. A Joint LVs table was created from the results of the three Joint and Single Service LVs (see Table 5 and Table 6). The tables were ordered by the questions significance (p-value) and weighted contribution to the CFA models.

It can be seen by comparing both tables, that question 9, 2, and 8 contributed the highest with an aggregated total (approx. 39%). In both cases, all but questions 5, 10, and 11 were statistically significant and those questions contributed the least to the CFA models. While the first nine questions contributed 92 – 95%, *Variability*, *Formal Links*, and *Give and Take* accounted for approximately 5 – 8% of the overall survey

responses. Coincidently, *Give and Take*, and *Formal Links*, were the non-Likert derived questions, and only *Variability* was part of the original set of nine questions.

Table 5 EFA Joint Combined LVs

Joint Combined LVs					
Question	Title	P Value	Contribution	Weighting	Acc %
9	Familiarity	< 0.001	0.73	0.1434	14.34
2	Concentration of Effort	< 0.001	0.64	0.1257	26.91
8	Access to Info	< 0.001	0.60	0.1179	38.7
3	Stability	< 0.001	0.58	0.1139	50.09
4	Difficulty	< 0.001	0.57	0.1120	61.29
1	Readiness	< 0.001	0.51	0.1002	71.31
7	Awareness	< 0.001	0.42	0.0825	79.56
12	Informal Links	0.008	0.35	0.0688	86.44
6	Coordination	0.024	0.27	0.0530	91.74
11	Formal Links	0.288	0.25	0.0491	96.65
5	Variability	0.336	0.13	0.0255	99.2
10	Give Take	0.679	0.04	0.0079	99.99

Table 6 EFA Single Service Combined LVs

Single Service Combined LVs					
Question	Title	P Value	Contribution	Weighting	Acc %
2	Concentration of Effort	< 0.001	1.21	0.1474	14.74
9	Familiarity	< 0.001	1.09	0.1328	28.02
8	Access to Info	< 0.001	1.04	0.1267	40.69
1	Readiness	< 0.001	0.97	0.1181	52.5
3	Stability	< 0.001	0.94	0.1145	63.95
7	Awareness	< 0.001	0.87	0.1060	74.55
4	Difficulty	< 0.001	0.79	0.0962	84.17
12	Informal Links	< 0.001	0.50	0.0609	90.26
6	Coordination	0.004	0.38	0.0463	94.89
5	Variability	0.074	0.25	0.0305	97.94
11	Formal Links	0.396	0.17	0.0207	100.01
10	Give Take	0.972	0.00	0	100.01

A modified 3-Dimensional cube plot was constructed that represented a weighted view from the CFA results. This was compared to the original equally-weighted cube, and similar clusters were identified. It was observed that the placement of the groups in relation to each other was similar, but that overall, the sample had shifted in three dimensional space, and some of the detail of the results had been lost.

Further analysis was conducted to determine what that meant. Also, by summing the Exploratory Factor Analysis results from Table 5 and Table 6, weighted responses for Joint, and for Single Service, can be obtained. These results of each participant's group were visualised onto a 2D XY chart that described a group's orientation, or 'Jointness', as shown below in Figure 3.

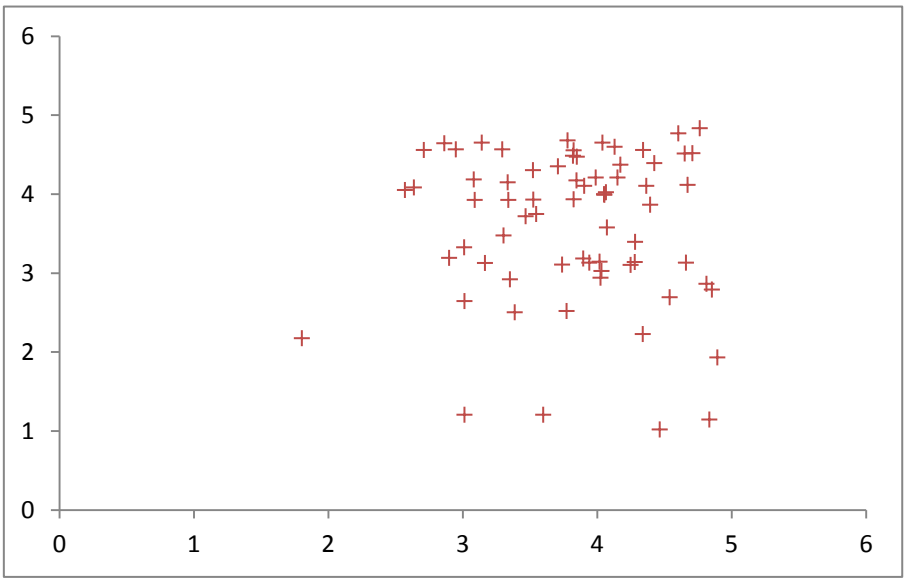

Figure 3 Respondent's Single Service-Joint score

A higher order attempt at analysis was tested using the Structural Equation Modelling (SEM) functions within AMOS that draws on a broader set of Factor Analysis techniques and combines them. SEM is used to see if observational errors can be removed from the latent variables that have been modelled [23]. The series of models that were constructed attempted to build upon each LV to see if an overarching model could be designed to describe 'Jointness' as a concept. To do this the individual models of the three LVs were then linked to create a SEM model for Joint, and one for Single Service, and see if this would change the overall weightings, or contributions and significance of the questions. This ideal SEM model is shown for *Single Service* in Figure 4 where the three CFA models can be seen [24]. However, the overall model was unidentified and did not fit. The low performing questions that were highlighted in the individual LVs were then removed to see if they impacted in a negative way, but still made no difference. The final results were inadmissible or inconclusive because the sample size, and the analysis could not account for all the variance in the model.

An interesting observation was that informal links contributed far more than formal links. Overall, both models demonstrated that there was a great deal of similarity in each question's contribution for both *Single Service* and *Joint*. However, this consistency of the two alternate tests demonstrated a level of confidence in the Latent Values and the data.

There was not enough data to create a complete Structural Equation Model, or an overall CFA model. Given the differences between the weighted and unweighted results, the low contribution of the latter three questions (Q 5, 10, and 11), and the inconclusive results due to sample size of the CFA model, further analysis of the differences was conducted. While CFA has been overtaken by an advanced Structural Equation Modelling software package called Analysis of Movement Structures (AMOS), CFA can still be performed within SPSS using Generalized Least Squares factor analysis [25 26]. Generalised Least Squares method was used to test

the data and highlight the goodness of fit of the data, and analyse the differences caused by the weighted results.

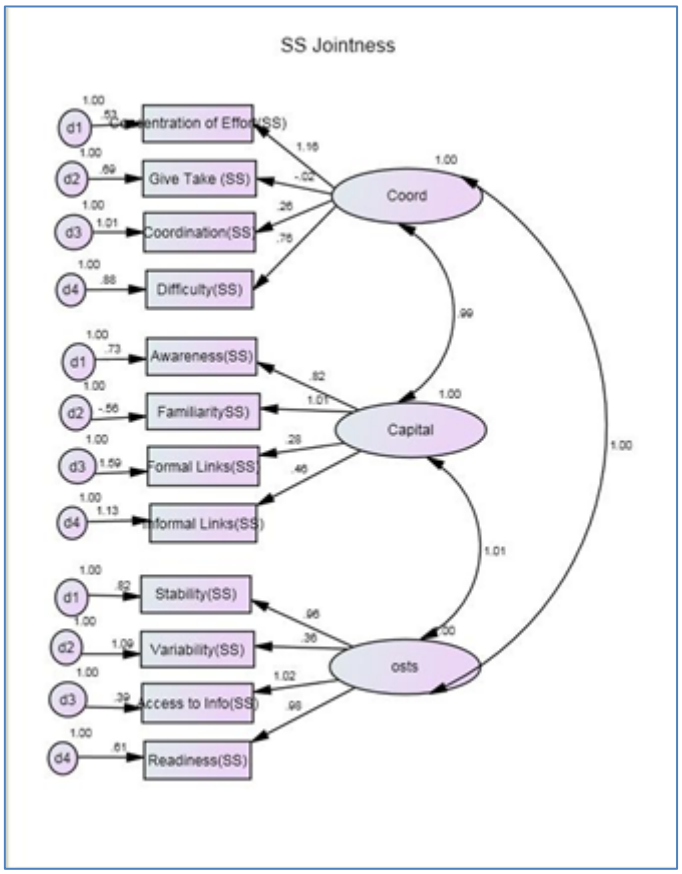

Figure 4 CFA model example

6. Analysis of Differences

The Generalized Least Squares (GLS) method is used to produce a goodness-of-fit table that can be used to test the hypotheses for the number of factors. It is important to note that a slight difference in terminology exists between the Principal Component Analysis used in Exploratory Factor Analysis, and Confirmatory Factor Analysis, where the term 'factor' is replaced with 'component' [27].

Overall, the results were the same as the earlier EFA. However, in both cases the p value was > 0.05 (0.584 for *Joint*, and 0.908 for *Single Service*), which suggested there was a problem with the distribution of the underlying data. Chi-Square testing was therefore conducted to further analyse the distribution of the data.

The Chi-Square statistic was used in a test of association between the survey response question and a subject. To test the hypothesis of no association between the eight question groups for the 68 responses. An eight by twelve column contingency table was constructed for both *Single Service* and *Joint* responses. The expected results were compared to the observed responses.

The value of the *Single Service* results was significant ($p < 0.0001$), and the Chi-Square result was high (187.8) indicating it would not support the hypothesis assumption because observed counts and expected counts would differ. There was a small probability that the results occurred by chance alone, and it can be concluded that association exists between the survey questions and the responses. This has been reflected in all of the results so far. However, in the first test 36 of the 96 expected responses (37.5%) were below what is considered good because the values were not greater than or equal to 5. This highlighted a problem with the distribution of the data.

The results above were reflected in the *Joint* analysis, but it was worse. While the result was significant ($p < 0.0001$), and the Chi-Square result was even higher (616), again indicating it would not support the hypothesis assumption because observed counts and expected counts would differ. There was an even smaller probability of the results occurred by chance alone. However, 48 of the 96 expected responses (50%) were below what is considered good because the values were not greater than or equal to 5. This also highlighted a problem with the distribution of the data.

For the comparison of differences to work, the data in Question 10, Give and Take, had to be rescaled. Again, the individual *Single Service* survey responses were counted to examine the expected responses to the questions and compare it to the observed responses. The results were: $X^{\wedge 2}$ (Chi-Square) = 187.8 with 44 degrees of freedom ($p < 0.001$). This time, none of the expected responses were equal to or below 5, and the changed grouping removed the initial problem of data distribution. The degrees of freedom have reduced from 77 down to 44, but the respective sampling distribution appears to be a normal distribution [28 29].

The *Joint* survey responses were not as good. This time, 12 of the expected 60 responses (20%) were below what is considered good because the values were not greater than or equal to 5. Again, this highlighted a problem with the distribution of the data. Yate's correction for continuity was applied to the Chi-Square test, which has the impact of making the results appear more conservative [30 31], but it made no impact in this case and the twelve responses.

The data was further reduced, and a four by twelve column contingency table constructed for the *Joint* responses. The results were positive this time, with none of the expected values falling below 5.

Overall the analysis highlighted the impacts of the way question 10 was structured, and that there was a propensity for respondents to answer the questions about *Joint* at the higher end of the response scale.

7. Discussion

Having sampled approximately 25% of all 1 Stars and Senior Executive Service Band 1's, it is acknowledged that the small sample size inhibited conducting all of the analysis, such as structural equation modelling, and also limited some factor analysis.

However, analysis of the EFA rotated component matrix highlighted between 6 and 8 of the 12 questions, or between 50 and 67% of the respondent's questions, fell within the correct theoretical LVs, or components model.

Adding new data outside of the initial set of nine questions, and increasing the number of questions to twelve and assigning them to the LVs increased the value of the results. While this highlighted other stronger associations in the data, it didn't affect the theoretical Latent Values, or constructs for use as a foundation for wider analysis.

Given the sample size, and both an overall tendency for respondents not to mark their scores at the lowset end of the response questions, and the half scores in question 10, the results are promising.

7.1 Key Findings and Observations

Joint is a complex and abstract concept at best, and given the variability of the joint activities selected by respondents, it was encouraging to determine a number of key findings and observations.

The study postulated that 'Joint' can be represented conceptually by a three dimensional space comprising: Coordination and Organisation; Social Capital; and Optimisation of the Socio-technical Systems. After analysis of the three LV's, or constructs, it is clear that there are similarities between the theoretical and observed constructs, and 'Joint' can be represented.

An examination of the CFA highlighted the value and contribution that informal links play over formal links. It also highlighted that there was a tendency for *Joint* staff to answer questions in the higher end of the bipolar scales, suggesting that people within these groups are reasonably aligned in the ADO.

A key observation is that the approach of analysing multi-faceted concepts of 'Joint', where a respondent can choose to answer their questions through their own lens, is a successful approach. In a longitudinal study, the meaning of Joint is likely to improve and become clearer over time, and survey responses would be higher again.

This work demonstrated that the existence of the LVs, or constructs, contribute to the underlying strength of the complex, multi-faceted Joint responses. Therefore we can use the statistical analysis and visualisation of this study with a measure of confidence and apply it to the data in support of wider aspects of the survey analysis.

8. Conclusion

This study began in 2012, when the Joint and Operations Analysis Division conducted a survey data collection activity with the aim of exploring the role of Joint in Force Design. The study postulated that 'Joint', is a complex and abstract concept at best, and can be represented conceptually by a three dimensional space

comprising: Coordination and Organisation; Social Capital; and Optimisation of the Socio-technical Systems.

This work is part of a larger body of work exploring Joint in the Australian Defence Organisation. The work, on representing Defence organisational entities within the Joint space, will be reported separately, but it is fair to say that the analytical techniques employed within this study provided a measure of confidence and validity to the survey data and demonstrated the value of the wider aspects of the survey analysis that was used in the larger body of work.

The analysis found that 'Joint' can be represented conceptually by the three dimensional space comprising: Coordination and Organisation; Social Capital; and Optimisation of the Socio-technical Systems, and it became clear that there are similarities between the theoretical and observed constructs on how 'Joint' was represented.

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Appendix A: Survey Questions

Table 7: List of survey question parts

Short Question	Long Question	Data Type
	SECTION ONE	
Question 1	Identify one (1) key joint activity and one (1) key single service activity	pick list
	SECTION TWO	
Question 2 Readiness	How ready is your branch to support the following at short notice?	Likert - 5 scale
Question 3 Concentration of Effort	How focused is your branch on responding to the following?	Likert - 5 scale
Question 4 Stability	How likely is it that your branch will be given new tasks in the following areas?	Likert - 5 scale
Question 5 Difficulty	How difficult do you estimate it would be for your branch to support the following?	Likert - 5 scale
Question 6 Variability	How much would your branch's work tempo change if suddenly called upon to support the following?	Likert - 5 scale
Question 7 Coordination	How much effort is consumed with coordination when your branch responds to the following?	Likert - 5 scale
Question 8 Situational Awareness	What level of prior awareness would your branch have if asked to support the following?	Likert - 5 scale
Question 9 Access to Information	Do you expect to have adequate access to the information you require to support the following?	Likert - 5 scale
Question 10 Familiarity	How familiar is your branch with supporting the following?	Likert - 5 scale
	SECTION THREE	
Question 11 Interactions	For the following question, consider the interactions you have with other areas in Defence.	Free text
Question 11 Interactions	In your branch's day-to-day business what are the branches or commands (1*/SES 1) you interact with the most?	Free text
Question 12 Direction	To what extent is your branch able to determine its own objectives and/or work program?	Likert - 5 scale
Question 13 Cooperation	To what extent do you rely on other branches in order to deliver your outputs?	Likert - 5 scale
Question 13 Cooperation	To what extent does your branch contribute to the outputs of other branches?	Likert - 5 scale
Question 14 Joint Outcomes	To what extent is your branch focused on delivering Single Service or Joint outcomes?	Likert - 9 scale

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19. ABSTRACT

In 2012 and 2013, the Joint and Operations Analysis Division conducted a survey data collection activity with the aim of exploring the role of Joint in Force Design.

The study postulated that 'Joint', is a complex and abstract concept at best, and can be represented conceptually by a three dimensional space comprising: Coordination and Organisation; Social Capital; and Optimisation of the Socio-technical Systems. Given the variability of the joint activities selected by respondents, and the small sample size, quantitative analysis was conducted on the collected data. This statistical analysis and visualisation helped triangulate the study's findings, and provided a measure of confidence in the respondent's complex, multi-faceted joint responses.

The analyses included Chi-Squared, Hierarchical and K-Means Cluster, Exploratory and Confirmatory Factor Analysis, and Generalised Least Squares. Three-dimensional cube visualisation and weighted two-dimensional representations of a group's measure of 'Jointness' were produced. These were used to relate participants views held on aspects of capital, coordination, and socio-technical systems.

This document will discuss the specific methods used and the insights gained as a result.