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# A STRUCTURAL PERSPECTIVE ON THE EMERGENCE OF NETWORK ORGANIZATIONS

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A network analytic approach to the study of organizational response to crises is used to determine the existence and form of integrated crisis management units (ICMUs). ICMUs are network organizations that emerge in response to severe crises such as major oil spills, earthquakes, hurricanes and other natural and man made disasters. Although ICMUs have received considerable attention from scholars in the form of empirical case studies, much remains unclear as to their nascent interorganizational structure and structural evolution. In this paper, we outline a network analytic framework for the study of ICMUs and demonstrate how some of the predictions of previous research can be more rigorously quantified and compared. We then apply our framework to the 1989 Exxon Valdez oil spill. The Valdez case study provides an illustration of the analytic framework and suggests some interesting directions for further research on emergent organizational forms. Results demonstrate (1) the emergence of a network organization which grew more complex and more centralized over time, (2) the vulnerability of emergent structures to after shocks, and (3) the structuration of the organizational field through coordination of multiple network organizations, despite fluctuation in peripheral groups of stakeholder organizations.

KEY WORDS: Organizations, social networks, crisis management, adaptation.

## INTRODUCTION

Network organizations are often seen as the organizational solution to turbulent and uncertain environments. However, little is known about

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the emergence of the network organizations, nor the impact that the emergence of such an organizational form will have on the structuration of the organizational field. A particularly turbulent environment is that of disaster response. If network organizations emerge spontaneously they should do so as part of the response to a major disaster requiring sustained interorganizational response. An example of such a disaster is the Exxon Valdez oil spill. In this paper, we examine the emergence of network organizations by exploring the emergence of a specific type of network organization, the integrated crisis management unit (ICMU), in a disaster response situation, the response to the Exxon Valdez oil spill.

Recent articles on network organizations essentially establish the nature, existence and prevalence of this form of organizing (e.g. Baker, 1992; Burns and Stalker, 1962; Mintzberg, 1979; Powell, 1990). Although there is some disagreement about what exactly constitutes a network organization, most researchers would agree that a possible form is a set of organizations that have a high degree of integration across their formal (interorganizational) boundaries and that can act, at least in certain domains, as a single coordinating unit (Baker, 1992; Powell, 1990). The ICMU is a network organization; it is composed of multiple highly interlocked organizations that nonetheless act more or less as a single entity to provide a coordinated response to the disaster. The high degree of integration is seen in joint meetings, activities, and individuals having temporary roles in two or more organizations and reporting to the collectivity not just the parent organization.

Network organizations are known to have emerged spontaneously in response to environmental demands and also by design (Baker, 1992). When faced with turbulence and uncertainty, network organizations are thought to be more effective than other coordination structures such as markets or hierarchies (Baker, 1992; Powell, 1990). Less is known, however, about how network organizations form, and how their development is tied to the structuration of the organizational field out of which they emerge. The work in disaster research is suggestive in this regard and much of what has been learned in studies of ICMU emergence during community and industrial disasters is relevant to the study of network organizations. Indeed, disaster response efforts are a good environment for checking the reality of organizational behavior against the theory (Carley and Harrald, 1997).



When disasters strike, particularly large scale disasters, interorganizational response is necessitated (Emery and Trist, 1965; Trist, 1977; Quarantelli, 1978). The set of organizations who respond form an organizational field that rapidly goes through a structuration process as responsibilities for response, and capabilities to respond, emerge. Preexisting contingency plans often fail to anticipate key events in the response phase and the need for a coordinated response among organizations. Thus, plans notwithstanding, the response organizations who make up the organizational field must often alter their relationships to each other and forge new ones rapidly. When a disaster strikes, rapidly evolving interorganizational networks become the media through which crisis response activities are coordinated. Within this network, the ICMU may come into being.

In this article, we demonstrate how the methods of social network analysis can be used to bring new insight to the question of the emergence of network organizations. This question has intrigued observers of interorganizational systems since ICMUs were first studied systematically (i.e. Dynes and Quarantelli, 1968). Specifically, "what is the interorganizational structure of an ICMU?"; "how does that structure evolve over time?"; and "how does structuration of the organizational field in response to a catastrophic event affect the emergence of a network organization?" are the questions we aim to address. Present theories make differing predictions about how network organizations, and hence ICMUs, should evolve structurally and how contingency plans ought to be designed (Harrald *et al.*, 1994). Various theoretical perspectives shed light on these issues.

The first theoretical perspective deals with the spontaneous emergence of a coordinating group. This perspective draws predominantly from the literature on emergent coordinating groups (e.g. Drabeck, 1986; Dynes and Quarantelli, 1968; Kreps, 1978; Dynes, 1978). Emergent coordinating groups are groups of organizations or people that spontaneously coalesce during crises to help manage the interdependencies of individual responding organizations and to reduce conflict (Dynes and Quarantelli, 1968). These emergent coordinating groups have many of the characteristics normally associated with network organizations. This literature suggests that in the event of a severe crisis, communities and organizations will spontaneously reorganize and a coordinating group will emerge and become more important throughout the response period (Quarantelli, 1988). The emergence of these groups is thought to be necessitated by the lack of appropriate contingency plans and the appearance of unanticipated stakeholders.

The second theoretical perspective suggests the presence and maintenance of a centralized system. This perspective draws from quite disparate sources including the work in resource dependency (Pfeffer and Salancik, 1978), institutionalism (DiMaggio and Powell, 1983; Meyer and Rowan, 1977), and that on the threat rigidity response (Staw *et al.*, 1981). According to this perspective, when an interorganizational system is faced with a severe crisis, a single organization or group of organizations will assume a strong leadership position from the outset. In part this is because the threat posed by a disaster causes the organizations to rigidify and centralize internally, and the network of ties among organizations to also rigidify and centralize. And in part, such centralized systems are necessary to reduce uncertainty about critical resources, and to provide legitimacy (by defining who is accountable). A variety of forces thus lead to the same conclusion – centralization. It is worth noting that such centralized systems are frequently designed into formal contingency plans in an effort to increase efficiency and reduce uncertainty. These formal plans legitimate certain ties and provide an institutional constraint that encourages the maintenance of a centralized structure. However, these plans and the centralized structures they entail sometimes have undesirable effects during crises (Harrald *et al.*, 1994; Perrow, 1984).

The third theoretical perspective focuses on distributed systems. This perspective draws largely from work on information processing and contingency theory (e.g. Carley, 1992; Galbraith, 1973; Lawrence and Lorsch, 1969; Malone, 1987), and that on disaster response (Comfort, 1994; Dynes and Quarantelli, 1968; Harrald *et al.*, 1990; 1992; 1994). According to this perspective the role of formal central authorities may be strong at first, but it will diminish over time as responding organizations coordinate their activities locally and laterally. Computational models (e.g. Carley, 1992; Carley and Lin, forthcoming), mathematical models (Marschak, 1955; Arrow and Radner, 1979), and human experiments (Cohen, 1962; Shaw, 1981) suggest that distributed team like structures respond quickly and accurately. As such, these structures are better for handling turbulent environments likes those posed by catastrophic events where it is important to respond in a timely and appropriate manner.



These three perspectives are rarely contrasted. In part, this is because empirical data and a generalizable methodology within the area of interorganizational structuration have not been available until relatively recently. We intend to contrast these perspectives empirically. We do this by restating these perspectives in terms of their "predictions" for the network of relations among organizations and the expected changes in those networks over time. We propose a simple network analytic framework and provide operationalizations of the prototypical ICMU structures implied by each of the foregoing theoretical perspectives. With these prototypical structures available for comparison, an exploratory analysis of the Exxon Valdez response is undertaken using data derived from newspaper coverage of the event and from the US Department of Transportation's official chronology. This study has all the limitations of a case study, we are after all looking at only a single, albeit important, disaster; but, it does illustrate the power of a network based approach for examining the emergence of network organizations.

## THE EXXON VALDEZ CRISIS

Shortly after midnight on March 24, 1989, the Exxon Tanker Ship Valdez ran aground, releasing approximately 11 million gallons of crude oil into the pristine waters of Prince William Sound and causing the worst disaster of its kind in North American history. By most accounts, the various public and private organizations that were formally responsible for responding to the spill were ill-equipped and ill-prepared. This disaster is interesting to theorists of interorganizational structuration, because a large number of organizations interacted during an extended response period, and because this was the first "test" of the formal response plan.

The challenge presented by 11 million gallons of free floating crude oil in a remote area known for its unpredictable weather may well have been insurmountable. However, much of the early failure of the Valdez response was attributed not just to insufficient resources; but also to poor interorganizational coordination. Original contingency plans not only failed to anticipate the size and location of the spill, but failed even to anticipate significant participation by the responsible oil company (Harrald *et al.*, 1992). These original plans were abandoned within the first 24 h (USDOT, 1993; Harrald *et al.*, 1992). As the spill appeared out of control, some participants in the response expressed frustration that "we were always reorganizing" (Harrald *et al.*, 1992). The US Coast Guard was officially in charge of on-scene coordination. Within the US Coast Guard, formal responsibility for coordinating the overall response was transferred three times during the first three weeks. This responsibility was ultimately assigned to Secretary of Transportation Skinner by President Bush to counteract a growing public perception that federal leadership was ineffective (USDOT, 1993). An integrated response, capable of making and implementing decisions, did not become stable until after the critical opportunity to deal with free floating oil had passed (Harrald *et al.*, 1990; 1992).

## DATA

Our analysis of the Valdez crisis focuses exclusively on the first 14 days following the oil spill. These 14 days represent the period of immediate response, and the transition from containment to cleanup activities. During this period formal contingency plans were abandoned and responding organizations struggled to coordinate their activities. We will examine this initial struggle by looking at the coordinative ties among the response organizations. After day 14, the task and the intra-organizational structure was substantially different.

Data on the relationships among response organizations was collected via content analysis of two documentary sources: (1) daily reports in the Anchorage Daily News, and (2) the official chronology of events as compiled by the US Coast Guard. As the local paper of record, the Anchorage Daily News provided a more thorough coverage of events during the crisis than did national and international news outlets.[1] The US Coast Guard is designated to serve as the Federal On

[1] Throughout the response period, the Anchorage Daily News consistently ran a greater number of articles per day (avg. = 4.8) than did the New York Times, for example (avg. = 2.9). Further, many of the articles appearing in other newspapers came over the wire service from the Anchorage Daily News. Concomitant international events such as the first Soviet election in 70 years naturally competed for print space within locally oriented newspapers. Insofar as this research is interested in establishing the size, composition and structure of the interorganizational response, breadth of coverage was an important attribute of the Anchorage Daily News as a data source.



Scene Coordinator (FOSC) for all off-shore oil spills by the National Contingency Plan. As such, the Coast Guard maintained a consistent role as a central archivist.[2]

Content analysis of newspaper accounts is one standard method for obtaining data about a community response to disaster events (Comfort, 1995). The availability of the Coast Guard chronology, however, provided an opportunity to examine the emerging response organization from a second perspective. Since the Coast Guard was in charge of coordinating the formal response, the Coast Guard data depicts the official ICMU. Meanwhile, the newspaper data depicts a more informal network. Together, these data sources reflect a response network that was rich in terms of the number of individual organizations involved, and dynamic in terms of its growth and structural change over time.

During the first 14 days of the crisis, the newspaper data reported the participation of 47 distinct organizations and the Coast Guard data reported the participation of an additional 39 for a total of 86 participating organizations. Once an organization appeared in a network sample on any given day, it's participation was assumed on all subsequent days.[3]

The master list of 86 specific organizations was reduced to 46 organizational actors through a process of categorization. Organizations were categorized according to the following rule: Any organization that failed to appear on at least two days within either data sample was assigned to an appropriate organizational category. For example, Greenpeace was mentioned as a participating organization only once (day 8) and only within the newspaper data. Greenpeace was therefore assigned to the "Environmentalist Groups" category. Any network ties recorded for Greenpeace on day 8 are treated as network ties involving Environmentalist Groups. In this manner, the size of the

[2] The official chronology of events was included as an appendix to the FOSC report published by the USDOT in June of 1993. This chronology was based on the daily response activities of the FOSC as reported and recorded in daily "pollution reports, Exxon summaries, and various correspondence" (USDOT, 1993: Vol. 2, p. 3).

[3] We assume that no organization completely withdraws from the response within the first 14 days. Anecdotally, there is evidence that no organizations withdrew during this period.

overall network was made manageable without sacrificing information from the original data.[4] The list of 31 organizations and 15 organizational categories is included as Appendix A. This categorization approach seemed reasonable as newspaper accounts rarely capture all of the participation on any given day. Further, given the nature of interorganizational responses to crises it is reasonable to assume that the behavior portrayed by organizations sampled by the news correspondents and official reports is reflective of the behavior of organizations of that type of organization particularly for peripheral actors. Detailed analysis suggested that this collapsing of peripheral organizations into categories did not substantively alter the results.

### Coordinative Ties

Within both data sets, coordinative ties between participating organizations were identified on each day. A coordinative tie was recorded between two organizations whenever a working relationship was mentioned between them by a newspaper article or by the Coast Guard chronology. For example, the *Anchorage Daily News* reported on March 25, 1989 that The Coast Guard and the state Department of Environmental Conservation (ADEC) officials immediately went out to the ship, some of them staying on the vessel through the rest of the day[5]. Information in this sentence was coded as a coordinative tie between the Coast Guard and ADEC.

To ensure the reliability of the coding strategy, a small sample of the newspaper articles and the Coast Guard chronology were reviewed and coded a second time by an independent rater with minimal

[4] The organizational categories, "state" and "federal" are exceptions. These categories also include unspecified references to the state and federal governments as well as to the Governor, and the President, respectively. Both the Governor and the President were mentioned a sufficient number of times within the Coast Guard data to warrant their inclusion as distinct organizations. However, disaggregation of these same categories within the newspaper data was not possible. Therefore, "state" and "federal" are left as amalgamated categories for the purpose of consistency across the two data sets.

[5] "Tanker Spill is Largest Ever in US", *Anchorage Daily News*, March 25, 1989.



training. Inter-rater reliability for the newspaper data was 82%. Inter-rater reliability for the Coast Guard data was 81%.[6]

With the coded data, twenty-eight $46 \times 46$ binary adjacency matrices were constructed. These represent two different snapshots (one for each source) of the interorganizational structure for each of the first 14 days of the crisis. All matrices of coordinative ties were symmetric.

### Technical Phases of the Early Response

The early response to the Exxon Valdez crisis was dramatically affected by prevailing weather conditions and a shortage of technical resources (Harrald *et al.*, 1992; USDOT, 1993). Without sufficient technical resources on hand, there was no opportunity to contain the spill in the vicinity of the tanker Valdez. Responding organizations had to struggle to keep pace with changing technical challenges while simultaneously negotiating new relationships. The effects of severe weather, the progress and changing characteristics of the spilled oil, and a steady inflow of new resources all affected the existence and evolution of the ICMU.

In accordance with these changing technical conditions, the evolving network was analyzed in four phases as shown in Table 1. Many response activities clearly stretched across the entire 14 days. However, the times at which particular technical challenges first became salient to the ICMU are used as phase demarcation points.

Weighted sums of the adjacency matrices for each day within each phase were calculated.[7] Then these sums, also $46 \times 46$ matrices, were dichotomized to yield final binary adjacency matrices for each

[6] To calculate the inter-rater reliability score, a selection of newspaper articles and sections from the Coast Guards FOSC report were chosen at random and coded by a second person, blind to the purposes of the study. Coding consisted of noting and counting the organizations mentioned in each article; then counting and noting the number of instances where organizations are mentioned as working together. For each article the number of unique counts by each rater was totaled for each category (organizations and organizational ties). Then, this total was divided by the sum of the unions of unique and nonunique counts to yield a percentage. The percentages reported above are averages across the several articles re-coded.

[7] Sums were weighted by the number of days within each phase.

TABLE 1
Technical Phases of the Early Valdez Response

| Phase | Time Period | Characteristic |
|---|---|---|
| 1 | Day 1–3 | *Salvage/recovery* – During this phase, response activities were dominated by efforts to refloat the Exxon Valdez and initial efforts to recover floating oil using insufficiently available skimmers, chemical dispersants, and *in situ* burning |
| 2 | Day 4–5 | *Storm* – During this phase, most of the response organizations were forced to look on as the floating oil slick stretched by more than 30 miles overnight |
| 3 | Day 6–9 | *Containment* – Emulsification of floating oil due to the storm rendered recovery efforts, especially *in situ* burning and chemical dispersants, ineffective. During this phase, mobilization began to protect vital fish hatcheries and shorelines as response equipment became more available and the spill threatened the Gulf of Alaska |
| 4 | Day 10–14 | *Beach cleanup* – During this phase, large scale beach clean up operations began in some heavily impacted areas |

phase.[8] The following results are based on analysis of these adjacency matrices.

## FORMALIZING THE THEORETICAL FRAMEWORKS

As previously noted, previous research suggests three alternatives for the form of an ICMU – emergent group, centralized system, and distributed system. The various perspectives make claims not only about the form of the resultant ICMU, but also suggest how the web of affiliations between organizations will change over time. Differences in these perspectives can be captured using standard social network measures such as: number of nodes and density. First we define those measures that are particularly useful in discriminating between the three perspectives we have identified. Then we operationalize the three perspectives by describing their predictions with respect to these measures. The particular structural measures that we will use are:

*Number of Nodes* The number of participating organizations during that phase of the response. This is important for descriptive reasons. Regardless of the perspective, the number of nodes is expected to increase over time as local and arriving organizations join the response effort. This is particularly true for very catastrophic events, as in such events most of the response units are not initially on-sight and it takes them awhile physically to arrive.

*Number of Isolates* The number of participating organizations that do not have ties with at least one other organization. This is useful in indicating the level of control of the ICMU.

*Density* The number of ties in the network divided by the number of possible ties. Network density is treated as a measure of the overall incidence of coordination among the organizations in the network.

*Connectivity* $1 - V/(n(n-1)/2)$, where $V$ equals the number of pairs of points that are not mutually reachable and the denominator represents the number of possible pairs (Krackhardt, 1994). This measure effectively counts and normalizes the number of subgraphs present in the network. Its value varies between zero and one. A network cannot be perfectly coordinated if subgraphs (unconnected factions) are present.

*Graph Efficiency* It is equal to $1 - V/\max V$, where $V$ equals the number of ties in excess of the $N - 1$ minimum number of ties required to connect the network (Krackhardt, 1994). Inefficiency, or a score close to zero, represents the presence of multiple paths between nodes. The higher the graph efficiency, the higher the centralization of a structure. We use this measure in addition to the more common measure of betweenness centralization as the response to a disaster may be controlled by a central core of organizations and not a single organization. Graph efficiency is better at reflecting centralization to a core of distinct units.

*Betweenness Centralization* The betweenness of the most central node divided by the maximum possible betweenness such a node could attain (Freeman, 1977). This measure also varies between 0 and 1; scores closer to 1 indicate that the network is coordinated by one central organization.

### The ICMU as an Emergent Coordinating Group

Dynes and Quarantelli (1968) first recognized the fundamentally interorganizational nature of community responses to disasters. Based on numerous case studies of disasters such as floods, tornadoes and

[8] The cut-off value used in the dichotomization procedure was the average cell value within the weighted sum matrices.

earthquakes, these authors developed a typology of organizational behavior under such catastrophic conditions. In disasters of significant magnitude, groups of organizations may emerge to play a significant role in a community's response. Emergent groups coalesce after the onset of a crisis to perform tasks for which their constituent organizations may have little previous experience or authority individually (Dynes and Quarantelli, 1968). Chief among these tasks is coordination. Dynes and Quarantelli (1968: p. 419), suggest "an *ad hoc* group made up of the city engineer, the county civil defense director, a local representative of the state highway department and a colonel from the Corps of Engineers who coordinate the overall community response during a flood" as an example of an emergent coordinating group. However, in catastrophic events, this emergent group is a collection not just of people, but of organizations. It is, in effect, a network organization.

According to Dynes and Quarantelli (1968), coordinating groups emerge as the end result of the escalating, sequential involvement of responding organizations. They emerge spontaneously to fill a sudden widely perceived need to resolve disputes and provide for overall coordination. However, emergent groups are difficult to study. They typically have no pre-disaster existence. They tend to dissolve once the crisis is over. They bear no name, and they do not have clear cut boundaries (Dynes and Quarantelli, 1968).

Despite these difficulties, previous research has drawn several conclusions about coordinating groups and when they emerge. For example, coordinating group emergence may be independent of the type of disaster, and dependent only on its scale (Stallings, 1978; Kreps, 1978), on the degree to which the crisis demands exceed available resources (Parr, 1970; Kreps, 1978), on the degree of ambiguity over legitimate sources of authority (Parr, 1970), or on the degree of atomization of community organizations prior to the crisis onset (Parr, 1970).

The coordinating group phenomenon has been studied primarily using reports by eye-witness informants and, when possible, direct observation by researchers. The occurrence of meetings of community leaders immediately following a disaster (Parr, 1970; Forrest, 1973) and the subsequent development of more formal interorganizational relationships (Forrest, 1978) have been treated as empirical evidence of coordinating group emergence. This approach has rendered valuable



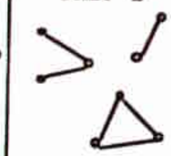
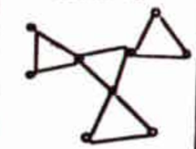
| | Time 1 | Time 2 | Time 3 |
|---|---|---|---|
| Emergent Coordinating Group |  |  |  |
| Structural Features | random | structuration | emergence of central group |
| isolates<br>density<br>connectivity<br>graph efficiency<br>betweenness<br>centralization | some<br>low<br>low<br>high<br>low | decrease<br>increase<br>increase<br>decrease<br>increase | decrease<br>increase<br>increase<br>decrease<br>level off |

FIGURE 1(a) Stylized portrayal of ICMU as an emergent group.

insights but it has not produced systematic, quantifiable, or necessarily non-case-specific measures. Nor has it allowed the researchers to determine empirically whether they were seeing an emergent group or a here-to-for unknown centralized structure or a distributed system.

A complementary approach considers coordinating group emergence from the perspective of the whole interorganizational system. Comfort (1988: p. 181), for example, refers to emergent coordinating groups as "natural networks" and Dynes (1970: p. 433) suggests that what emerges are "patterns of interaction among the members of the developing subsystem."

A stylized representation of the emergent coordinating group phenomenon is shown in Figure 1(a). Responding organizations are represented as nodes in an evolving network; the incidence of coordination between any two organizations is represented as a network tie. If the ICMU evolves as an emergent coordinating group, then early in the crisis response (at time 1), individual organizations are disconnected.[9] But as time progresses (through time 2), organizations begin to

[9] The time frames in Figure 1(a) and (c) are chosen arbitrarily for the purpose of illustrating a hypothetic ICMU network's evolution over time. In an actual case, the rate of evolution would likely be dependent upon specific crisis related contingencies.

establish relationships with their neighbors until finally (at time 3), a coordinating group emerges from among participating organizations to more effectively manage their interdependencies; the ICMU network becomes connected. These claims can be interpreted more formally in terms of the foregoing measures of the interorganizational network.

*Number of Isolates* If an ICMU evolves as a emergent coordinating group, the number of isolates is expected to decrease as responding organizations increasingly establish relationships with their neighbors to meet the demands of the crisis.

*Density* If an ICMU evolves as a emergent coordinating group, density will be very low at the beginning of the response but will increase steadily over time.

*Connectivity* If an ICMU evolves as an emergent coordinating group, connectivity will be low at the start of the crisis response, but should approach 1 as the response develops.

*Graph Efficiency* If an ICMU evolves as an emergent coordinating group, graph efficiency will be high at the start of the response, but will decrease as the ICMU evolves.

*Betweenness Centralization* If an ICMU evolves as an emergent coordinating group, then this measure will start low, and increase until the coordinating group has emerged, and then level off. The measure should never approach 1.

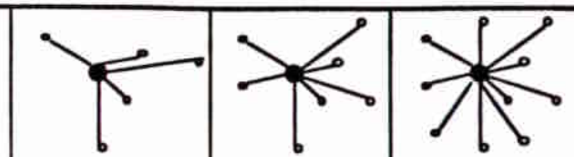
### The ICMU as a Centralized System

Several theories of organization suggest that network organizations, such as ICMUs, will have a centralized structure. Both institutionalism (DiMaggio and Powell, 1983; Meyer and Rowan, 1977) and resource dependence theory (Pfeffer and Salancik, 1978) suggest that over time within interorganizational networks individual organizations with the ability to be held accountable, or to confer legitimacy or resources to others will emerge in positions of power at the center of the network. The threat rigidity hypothesis offered by Staw *et al.* (1981) if applied to interorganizational networks, suggests that in times of stress, such as during disaster response, this centralization tendency will be magnified.



Previous organizational case studies have shown that as organizations respond to crises, access to timely and accurate information (Comfort, 1995; Perrow, 1984; Tierney, 1994) and the degree to which organizations share a frame of reference (Shrivastava, 1987) can affect their overall success. With this in mind, designers of formal contingency plans frequently design ICMUs with information processing efficiency and reduction of uncertainty as primary goals. However, their designs frequently may entail a "closed system" logic for all that they attend to external pressures (Harrald *et al.*, 1994). Closed systems employ centralized, hierarchical organizational structures developed in planning stages prior to the crisis onset. In closed, centralized systems, formal officials direct activities, and communication occurs through predominantly vertical channels (Harrald *et al.*, 1994).

Thus, there are several factors that may push ICMUs toward centralization as they develop. Figure 1(b) depicts a stylized portrayal of the development of an ICMU as a centralized system. The large central node in the diagram represents a pre-determined coordinating organization or small group of organizations that directs the activities of other organizations. Over time, the network grows in complexity but remains highly centralized.



| Centralized System | | | |
|---|---|---|---|
| Structural Features | pre-existing centralized group | increasing centralization | increasing centralization |
| isolates | high | decrease | decrease |
| density | high | decrease | decrease |
| connectivity | high | high | high |
| graph efficiency | high | high | high |
| betweenness centralization | high | high | high |

FIGURE 1(b) Stylized portrayal of ICMU as a centralized system.

*Number of Isolates* If an ICMU is a centralized system, then the number of isolates is expected to decrease as responding organizations increasingly establish relationships to the central node thereby contributing or securing resources or gaining legitimacy for their actions.

*Density* If an ICMU is a centralized system and the number of response organizations grows over time, then the density of the interorganizational network should decrease over time.

*Connectivity* If an ICMU is a centralized system, then connectivity will remain high throughout the response.

*Graph Efficiency* If an ICMU is a centralized system, then graph efficiency will remain high throughout the response.

*Betweenness Centralization* If an ICMU is a centralized system, then betweenness centralization will remain high throughout the response.

## The ICMU as a Distributed System

Information processing and contingency theorists would recommend that network organizations in turbulent environments take on a more decentralized form (Carley, 1991; Galbraith, 1973; Malone, 1987). Several organizational studies have demonstrated that an organization's performance is enhanced when the complexity of its structure is matched with that of its task environment (Carley and Lin, forthcoming; see also Lawrence and Lorsch, 1969). Especially when organizations are under a high degree of stress, distributed structures outperform simple hierarchies on complex tasks (Carley and Lin, forthcoming). The value of flexibility, and of lateral ties between organizational divisions or subsystems has been further corroborated by Krackhardt and Stern (1988) in their examination of performance under stress, and by Malone (1987) in his examination of "decentralized markets" as coordination structures.

In truly catastrophic events, highly centralized systems may actually be dysfunctional (Carley, 1992; Harrald *et al.*, 1994). Different kinds of groups may emerge as part of the response effort. Stakeholder groups, for example, may coalesce around particular aspects of a crisis or around particular threatened resources. Such unanticipated stakeholders can severely complicate and disrupt a formal centralized structure (Harrald *et al.*, 1994; Perrow, 1984). Further, large scale crises



are dynamic events in which time is a critical factor. To the extent that necessary interorganizational relationships and goals can be identified in advance, the likelihood of overall success is increased. Thus, contingency plans are vital, but according to this perspective, ICMUs must evolve rapidly into distributed systems. Distributed systems allocate decision making authority to the lowest levels and so admit more rapid response to emergent problems. Thus, from a pragmatic or contingency planning perspective ICMUs should be organized as distributed systems (Drabeck, 1986; Harrald *et al.*, 1994).

Harrald and his colleagues have examined particular disaster situations and provided a theoretical approach to the design of ICMUs specifically for catastrophic oil spills (Harrald *et al.*, 1990; 1992; 1994). Their work draws on both the organizational and the contingency planning research cited above and on research concerning the design of high reliability organizations (Perrow, 1984). They suggest that a more distributed team like structure is the most effective structure for a network organization in a turbulent environment. The organizational structure of the network organization should not be pre-planned or rigid; but should evolve based on feedback. Further, according to this perspective network organizations should rely on informal, lateral communications, and should reflect external influences such as stakeholders (Harrald *et al.*, 1994).

Figure 1(c) presents the evolution of an ICMU as a distributed system. At time 1, some pre-determined central organizations (the dark nodes) may execute initial contingency plans. At time 2, other responding organizations arrive on the scene and begin to establish network ties. The structure is flexible so that any unanticipated emergent groups of organizations are quickly integrated (tied in). By time 3, the coordination structure becomes distributed. Here, individual organizations coordinate their activities informally and efficiently and the role of the organizations that originally initiated the response becomes less critical (Harrald *et al.*, 1994), while centralization and graph efficiency should decrease.

*Number of Isolates* If an ICMU evolves as a distributed system, then the number of isolates will fluctuate over time as stakeholders come and go.

*Density* If an ICMU evolves as a distributed system, then density should increase steadily over time.

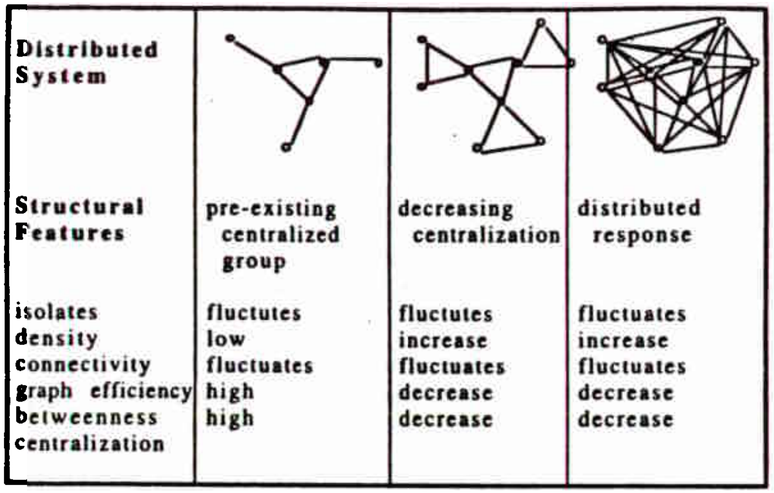



FIGURE 1(c) Stylized portrayal of ICMU as a distributed system.

*Connectivity* If an ICMU evolves as a distributed system, then connectivity will fluctuate over time as the number of stakeholders changes and temporary alliances form and reform.

*Graph Efficiency* If an ICMU evolves as a distributed system, then graph efficiency will decrease over time as the role of the initial formal coordinating body decreases.

*Betweenness Centralization* If an ICMU evolves as a distributed system, then betweenness centralization will decrease over time as the role of the official coordinators decreases.

## NETWORK ANALYSIS RESULTS

Results of the network analysis highlight three interesting phenomena during the Exxon Valdez response: (1) As the ICMU evolved, it emerged as a system, centralized around key official coordinators. (2) The ICMU was highly vulnerable to the "after shock" represented by the storm that occurred on day 4. (3) Finally, as the ICMU became more centralized, several groups of stakeholder organizations emerged and submerged on its periphery leading to a combined distributed and centralized response.



TABLE 2
Aggregate Structural Measures: Combined Network

| | Phase 1: Salvage/recovery | Phase 2: Storm | Phase 3: Containment | Phase 4: Beach cleanup |
|---|---|---|---|---|
| Number of nodes | 30 | 36 | 43 | 46 |
| Number of isolates | 3 | 19 | 13 | 7 |
| Network density | 0.14 | 0.04 | 0.07 | 0.07 |
| Betweenness centralization | 25.47% | 11.19% | 23.19% | 38.14% |
| Graph efficiency | 0.89 | 0.88 | 0.90 | 0.94 |
| Connectivity | 1.0 | 1.0 | 1.0 | 1.0 |

In order to evaluate the evolving structure of the ICMU, we begin by combining data from the newspaper and Coast Guard sources to form a single network representation for each phase. The official and informal adjacency matrices within each phase were added together, and then dichotomized as previously described. The results shown in Table 2 indicate that the evolution of the ICMU cannot be completely characterized by any of the foregoing perspectives. We find no support for the emergent group perspective, other than the increase in betweenness centralization from phase 2 on. Consistent connectivity scores of 1.0 indicate that, even at the earliest stages, only a single subgraph was present in the network.[10] Thus, the ICMU did not evolve as an emergent coordinating group.

The observed behavior is most consistent with the centralized system perspective: that is, the level of connectivity and graph efficiency are high and remain high. Further, from phase 2 on the number of isolates decreases. Consistent with the centralized system perspective there were a set of official responding organizations and they are the most central organizations. Of the four most central organizations in the network during phase 1 (Exxon, the Coast Guard, Alyeska, and the ADEC), all but Exxon were planned first responders. These were the organizations that were officially supposed to respond. Upon being informed of the grounding, the Coast Guard initially responded according to plan by notifying ADEC, the other members of the Regional Response Team, and Alyeska, the firm originally responsible for mobilizing salvage and recovery resources (USDOT, 1993).

[10] Connectivity score of 1 persist even when the data is disaggregated to the level of daily network samples.

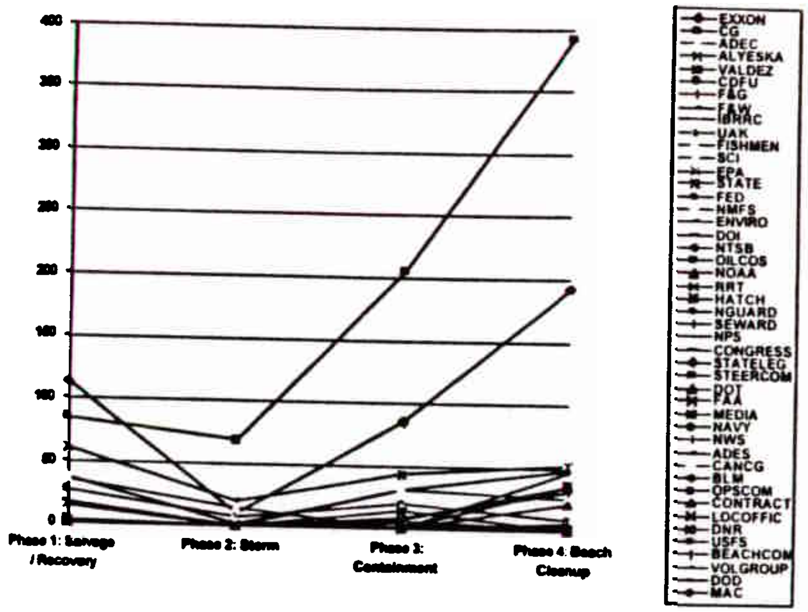



FIGURE 2 Changes in each organisation's betweenness score.

In Figure 2, betweenness centrality scores for each individual organization are shown. The two increasingly most central organizations were Exxon and the Coast Guard. During phase 1, ADEC and Alyeska had also played significant coordinating roles, but once the storm had passed, the ICMU was clearly dominated by the Exxon-Coast Guard pair. This basic pattern of increasing centralization holds independently in both the newspaper and the Coast Guard data. Further, in both data sets the Exxon–Coast Guard pair is critically central. The centrality and growing centrality of this pair is consistent with the centralized system perspective.

However, the response was not just a simple case of a centralized and increasingly centralized response effort. Rather, the distributed system perspective receives a little support. In particular, the movement from phase 1 to 2 matches many of the expected patterns. And, as suggested by the distributed perspective, as new tasks emerged new organizations and groups of organizations began to play a coordinative role (notice the fluctuation in betweenness centralization). That the pre-existing contingency plans influenced the initial characteristics



of the ICMU but were abandoned within the first few hours is further corroboration of the distributed perspective.

Thus, in the final analysis, none of these perspectives completely characterizes the response effort and the emergence of an ICMU. Although there is a strong tendency toward centralization there is also a fluctuating distributed group. Additionally, we found that chance or historical accident played a critical role in determining the form of the emergent network organization. Chance took the form of a storm. The data reported in Table 2 indicate that the storm had severe effects on the interorganizational network. Network density, a measure of the overall incidence of coordination, decreased dramatically during phase 2 (from 0.14 to 0.04) and never recovered. Then, after the disruption of the storm, betweenness centralization and graph efficiency increased steadily, suggesting that the ICMU was increasingly arrayed around a few key central organizations. Both data sets, collectively and independently, show that the storm during phase 2 had dramatic effects.

To further explore the nature of the emergent ICMU we now examine the two data sets separately. This more detailed analysis provides a closer look at differences between the official (Coast Guard) and informal (newspaper) accounts of the ICMU structure during the response effort. As previously mentioned, there are striking similarities between the two sets of data. Both depict the same organizational actors as being central and both show a disruption due to the storm. During phase 3, while both data sets depict the ICMU recovering from the storm and becoming increasingly centralized, they differ somewhat in their details. In fact, the ICMU structure portrayed by these two sources becomes increasingly dissimilar with time. The QAP correlation (Krackhardt, 1988) between the Coast Guard and newspaper data drops from 0.20 in phase 1 to 0.13 in phase 4 (this drop is significant at the 0.05 level).

The official Coast Guard data exhibits significantly higher graph efficiency, lower density and fewer cliques than the newspaper data. In the top panel of Figure 3, we can see that the structure of the response network portrayed by the Coast Guard during phase 4 was almost entirely structured around the central Exxon-Coast Guard dyad.[11]

[11] This figure was generated using Krackplot 3.0 (Krackhardt *et al.*, 1994).

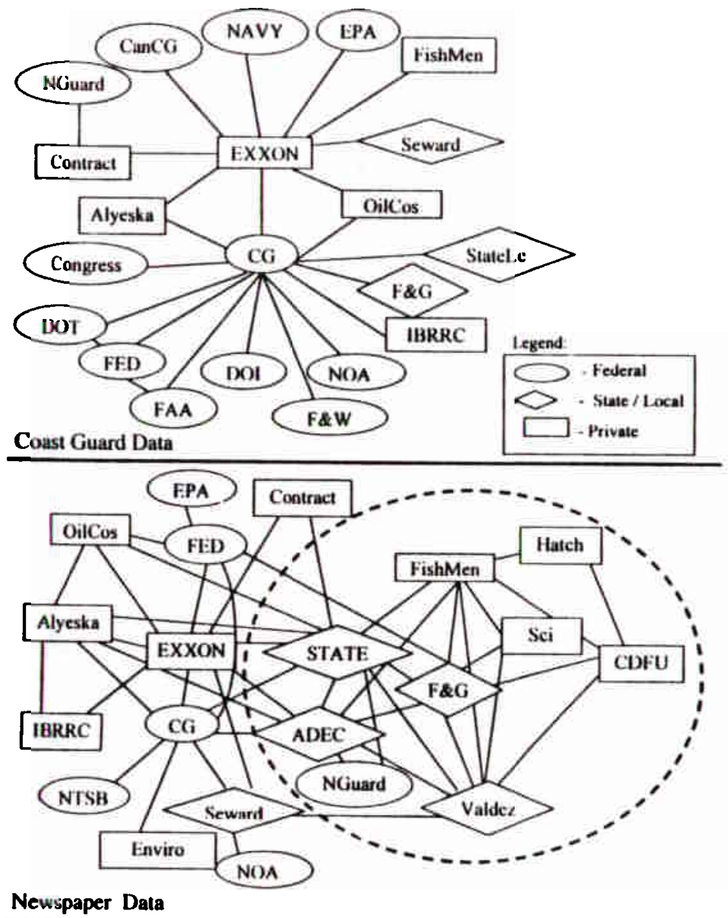



FIGURE 3 Emergence of stakeholder groups.

Almost exclusively, other organizations were either isolates or they were tied to this pair. The coordinating roles of ADEC and Alyeska vanished from the ICMU as reported by the Coast Guard during phase 3. In other words, looking only at the Coast Guard data, we would have had unequivocal confirmation of the perspective that the emergent network organization is a centralized system. In some sense, the structure portrayed by the Coast Guard reflects the official or formal roles that Exxon and the Coast Guard had to hold, and did hold, during the response for both institutional and resource dependency reasons.



The newspaper data tells a somewhat different story. Here, groups of state and local organizations are seen forming on the periphery of the official ICMU. In the bottom panel of Figure 3, we can see the structure of the response network during phase 4 as reported in the newspaper. To be sure, the official ICMU, that seen in the Coast Guard data, appears almost as a subset of what is seen in the larger network. However, within the newspaper data we also see that the State and ADEC serve together as a bridge between two apparent factions: a group of organizations that closely resemble the official ICMU (as reported in the Coast Guard data), and a group of emergent cliques involving local stakeholders such as fishermen, hatcheries, the Cordova Fishermen's Union, scientists, and the cities of Valdez and Seward. These stakeholders were coordinating their activities with each other, but their activities were not recorded as part of the official Coast Guard report. In part this is because these local stakeholders were working on different task than was the Coast Guard. The official ICMU was principally concerned with containment and oil recovery, at least initially. Whereas, many of the initial stakeholders were concerned with environmental or livelihood protection. In summary, looking only at the newspaper data we see support for the distributed system perspective.

There is some evidence that the official coordinators failed to integrate emergent stakeholders quickly. Certainly we see that in the official report, these emergent stakeholders were so peripheral that they did not even appear to play a role in the response effort. This failure probably contributed to poor overall perceptions of the official coordinators effectiveness (Harrald *et al.*, 1992; 1994). Other sources corroborate this story. During phase 3, significant conflicts between key participating organizations began to erupt. On day 5, for example, the Governor of Alaska began calling for federalization of the formal response out of frustration with Exxon's performance (NY Times, March 29, 1989). Exxon and the Coast Guard reportedly spent too much time experimenting with recovery techniques that had been rendered useless when the storm emulsified the floating oil (USDOT, 1993). Groups of local stakeholders, frustrated with Exxon, reportedly moved on their own initiative to protect vital fish hatcheries and newly threatened areas as the oil slick stretched into the Gulf of Alaska (NY Times, March 29, 1989; USDOT, 1993).

## DISCUSSION

Further network studies of ICMUs are necessary to determine whether the pattern that we observed is typical for network organizations. The network analytic framework employed here is valuable both because it enabled us to contrast multiple perspective and because it permits subsequent comparison of by other researchers using other data sets.

Disasters, particularly catastrophic events such as the Exxon Valdez, are complex events. No single methodology or level of analysis is sufficient to comprehend fully their characteristics. While the method employed here provides a new structural understanding of the phenomena, it has some weaknesses. Most importantly, the method treats all nodes in the network as indivisible and identical. Clearly, individual organizations, and units within organizations, may not all respond identically to large scale crises. Secondly, the network method alone does not inherently permit distinctions between effective and ineffective structures. The effectiveness of an ICMU may be affected by the individual structure and effectiveness of all of its constituent organizations. Consequently, more in-depth intraorganizational information should be sought to qualify appropriately the kind of evidence of interorganizational coordination that is presented here.

One of the strengths of this analysis is that were able to use both the official FOSC's report and the newspaper data. However, newspapers and archival sources such as those employed here represent the only available sources of network data for large scale crises. Such events do not permit the use of survey instruments. Nevertheless these sources of data suffer certain biases. For example, the Coast Guard data may have focused more on those organizations playing a legal or official role. Whereas, the newspaper data may have focused proportionally more on unofficial activities. Thus, utilizing multiple sources is critical as it gives a more comprehensive picture.

In particular, published newspaper articles do not represent an unfiltered source of information. Reporters are more likely to report information obtained from sources with whom they have pre-established relationships. Thus, the newspaper data is somewhat likely to have overstated the role of the state (including the Governors office) and other organizations that were more aggressive and organized in providing the media with particular messages to broadcast. Reporter's



stories also undergo a significant amount of editing prior to publication. Thus, some information may have been lost due merely to competition with other stories for print space. However, significant crises also compel the media to provide broad coverage of events to respond to a dramatically increasing demand for information. Media outlets are subject to an "unrelenting pressure" to provide fresh accounts. Such pressure may tend to distort the events reported but also drives reporters to expand the numbers of people they interview from different perspectives. Since the content analysis conducted for this research considered only whether organizations and ties were present, that pressure toward breadth of coverage is actually desirable.

Interestingly, this work on disaster response has largely been overlooked by organizational theorists. We find that by bringing together disaster response research, network theory, and organizational theory provides a better understanding of the emergent forms of network organizations. Although numerous other studies of interorganizational networks have been done (see Mizruchi and Galaskiewicz, 1994, for a review), most have investigated a network's effect on individual organizations rather than the overall structural evolution or effectiveness of an interorganizational network at achieving some common goal.[12] When such common goals are present, the interorganizational network may form a network organization. We suggest that the framework outlined can be gainfully employed in further studies of network organizations in general, and ICMUs in particular, to address these important issues organizational evolution.

A particular feature of disaster response is that it is, at best, a temporary activity. Thus, the network organizations that emerge in response to a specific disaster may not last past the span of that event. The first point, is this transience should be tested. Are the structures that emerge really all that transient? While a specific disaster is a rather unique occurrence, classes of disasters are not. Thus, the reason that a centralized network organization, like that focused around the Coast Guard and Exxon may appear to emerge is because it is an ongoing form that moves between events. Whereas the more distributed structures may be local to specific events. The second point is

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[12] Provan and Milward (1995) demonstrate that the overall success of networks of community mental health service providers is predicted by overall network centralization, but there are other examples at present.

that disaster response may be a useful environment for examining the dissolution of interorganizational forms as well as the emergence of forms.

This analysis has suggested that the perceived coordination failure in the Exxon Valdez response may have been due to a clash between emergent network organizations with alternative structures – the official centralized ICMU and the distributed stakeholder ICMU – and the failure of the two types of network organizations to integrate in a timely fashion. Other than this story of coordination failure, these data suggest another lesson for our understanding of the emergence of a network organization. These data suggest that in turbulent environments multiple network organizations emerge. Moreover, each of these network organizations may have a different structure because the environment *per se*, does not dictate its form. Rather chance (the storm), task (containment/recovery versus protection), and formal position (coordinative roles defined by a contingency plan) all enter into determining the structure of the network organizations that emerge and the links between them.

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## APPENDIX A: CONSOLIDATED LIST OF PARTICIPATING ORGANIZATIONS

| | *Code* | Organization(s) |
|---|---|---|
| 1 | Exxon | Exxon Shipping Co. |
| 2 | CG | US Coast Guard |
| 3 | ADEC | Alaska Department of Environmental Conservation |
| 4 | Alyeska | Alyeska Pipeline Service Co. |
| 5 | Valdez | City of Valdez |



(*Continued*)

| | Code | Organization(s) |
|---|---|---|
| 6 | CDFU | Cordova District Fishermen's Union |
| 7 | F&G | Alaska Department of Fish and Game |
| 8 | F&W | US Fish and Wildlife Service |
| 9 | IBRRC | International Bird Rescue and Research Center |
| 10 | UAK | University of Alaska |
| 11 | Fishmen | Misc. Fishermen |
| 12 | Sci | Misc. Scientists |
| 13 | EPA | US Environmental Protection Agency |
| 14 | State | Includes references to the Governor, the Alaska Department of Public Safety, the Alaska Attorney General, and unspecified references to Alaska State Government |
| 15 | Fed | Includes references to the President, the Federal Emergency Management Agency, The US Department of Commerce, the US Air Force, and unspecified references to the federal government |
| 16 | NMFS | National Marine Fisheries Service |
| 17 | Enviro | Environmentalist groups: Includes the Natural Resources Defense Council, the Audubon Society, Greenpeace, and references to unspecified environmentalists and activists |
| 18 | DOI | US Department of the Interior |
| 19 | NTSB | National Transportation Safety Board |
| 20 | Oilcos | Misc. Oil Companies |
| 21 | NOAA | National Oceanic and Atmospheric Administration |
| 22 | RRT | Regional Response Team: An interorganizational group specified by the National Contingency Plan including members from the Coast Guard, EPA, DOI, NMFS, NOAA, ADEC, and ADF&G |
| 23 | Hatch | Hatcheries: Includes the Prince William Sound Aquaculture Association, Chugach Corp, and unspecified references to fish hatcheries |
| 24 | NGuard | Alaska National Guard |
| 25 | Seward | City of Seward |
| 26 | NPS | National Park Service |
| 27 | Congress | Includes any members of the US Congress, and any unspecified references to the House or Senate |
| 28 | StateLeg | Includes any members of the Alaska State Legislature |
| 29 | SteerCom | Steering Committee: An emergent informal committee comprised of Exxon, ADEC and Coast Guard leaders (established on day 4) |
| 30 | DOT | US Department of Transportation |
| 31 | FAA | Federal Aviation Administration |
| 32 | Media | Includes any reference to the news media |
| 33 | Navy | US Navy |
| 34 | NWS | National Weather Service |
| 35 | ADES | Alaska Department of Emergency Services |
| 36 | CanCG | Canadian Coast Guard |
| 37 | BLM | US Bureau of Land Management |
| 38 | OpsCom | Operations Committee: An emergent interorganizational group comprised of the Coast Guard, RRT, ADEC, ADES, and fishermen's representatives (established on day 5) |

*(Continued)*

| | Code | Organization(s) |
|---|---|---|
| 39 | Contract | Misc. contractors: Includes VECO corp., VRCA Environmental Services, Underwater Construction, Inc., and unspecified references to vessels, divers and workers employed in the response effort |
| 40 | LocOffic | Local Officials: Includes unspecified references to local police and government |
| 41 | DNR | Alaska Department of Natural Resources |
| 42 | USFS | US Forrest Service |
| 43 | BeachCom | Beach Cleanup Committee: An emergent interorganizational group to set priorities and strategies for beach cleanup, includes: ADEC, USF&W, ADFG, NOAA, ADNR, USFS, Fishermen, Chugach corp., Exxon, EPA, Contractors, and members from affected public (established on day 9) |
| 44 | VolGroup | Misc. Volunteers |
| 45 | DOD | US Department of Defense |
| 46 | MAC | Multi Agency Committee: An interorganizational group including Seward, NPS, Alaska State Parks, Kenai Borough, Misc. Contractors, and Exxon |