Supporting Multi-Group Emergency Management with Multimedia*

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Abstract:
Many different groups of experts are involved in the management of complex large-scale operations during normal operation and also in cases of emergencies. Advanced communications and information processing technologies (e.g., multimedia and the Internet) provide the basis for real-time decision support for emergency response. However, to assure effective information processing and decision making, the technology must be complemented by sophisticated analysis and decision making models. In this paper we discuss the concept of emergency management for multiple groups of experts, and propose a decision support approach which capitalizes upon advanced multimedia technology. The concept is based on an expanded paradigm of Operational Risk Management which is based on the concept of assessing and revising courses of action in a real-time environment. The approach is discussed for the case of an emergency response organization in a nuclear power generation plant.

Keywords: Decision Support Systems, Operational Risk Management, Multimedia, Emergency Response, Nuclear Power Generation.

1. INTRODUCTION

A major concern for an industrial operation is to know how to handle sudden onset incidents which occur very infrequently but which have potential detrimental consequences. The crucial aspect in emergency management refers to the timely collection, processing, and dissemination of data, as basis for decision making. Traditionally, a set of alternative response plans are devised in a strategic manner [2]. Unfortunately, unexpected events (called Real-Time Event) can occur for which no plan has been devised. In such instances, the operators must investigate, and possibly change, these strategically devised plans to prevent or mitigate the potential consequences.

In large industrial organizations, however, the assessment and decision making process must be done rapidly under stressful conditions, involving different groups of experts. To cope with the combinatorial complexity of assessing and revising courses of action, Beroggi and Wallace [2] have proposed a graph theoretical approach for real-time emergency management. This new decision making paradigm was originally devised for an individual decision maker (operator) but later on extended to include multiple experts and is called multi-expert operational risk management [5].

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increasing severity of the event. For the purpose of this discussion, it will be either the operators or the management group.

The objective of the emergency organization and of the groups and their members is to resolve the emergency situation and to return the operation to a normal state. Therefore, any decision support technology must aid all the groups in: (1) Monitoring, (2) Real-Time Information Exchanging, (3) Interconnectedness, (4) Real-Time Recommendation-Generation with Preference Values, (5) User-Friendly Interfaces, and (6) Targeted Information Display[1]. However, most crucial is that the technology includes a modeling capability that provides the groups with the cognitive support needed to facilitate decision making in the stressful situation of emergency response.

2.1. Preference Structure

Real-time events have the potential to set off an emergency and, in the course of an emergency, to make the emergency more severe and harder to control [2]. It is therefore of major importance that the groups and their members be aware of all real-time events.

To provide effective decision support, a reasoning model must be devised which generates a set of recommendations in real-time and orders them according to the groups' preferences. The concept of the reasoning logic is described in Beroggi and Wallace [2]. A course of action (e.g. response plan) consists of a concatenated set of decisions and subsequent actions. A compact way to represent the courses of action and their relations is to use a graph structure, where the decisions to take an action are the nodes (desision nodes) of the graph and the actions the links between two decision nodes. A specific course of action can therefore be seen as a "path" on the decision-action graph. We assume that the preference of taking an action under normal conditions (i.e. as planned strategically) is assessed in terms of different attributes, such as risks to humans, operational costs, and risks to the environment. These attributes should not be interpreted as evaluation criteria. Rather, they should be seen as preference classes which are related to each other by a complete strong preference structure, stating, for example, that high risks are of higher concern than operational costs. In case a real-time event occurs, the preferences of the actions which are affected by the event must be reassessed. With these reassessed preferences, new optimal courses of action can be computed.

The reasoning logic takes into account four components: (1) the large-scale operational system, which is supposed to behave according to strategically designed courses of action; (2) the unexpected real-time events that have an impact on the expected achievement of the planned courses of action and that cannot be considered strategically; (3) the human-machine system that (i) monitors the large-scale operational as part of passive operational risk management , (ii) assesses impacts of real-time events on the planned course of action as part of active operational risk management, and (iii) if necessary revises the course of action as part of active operational risk management, and (4) recommendation generating capability that ranks recommendations according to the emergency situation, including the potential for catastrophic impacts and the responsibilities of the users.

When all preferences of all activities are assessed, the overall preference of a course of action, or parts of it, can be computed. The preference of two consecutive activities is the "sum" of

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[1]To avoid an information overload, the system displays must be designed to provide only the information appropriate for particular groups, based on their responsibilities.

The focus of the research reported in this paper is on providing effective decision support for groups of experts engaging in emergency response, with special attention given to the dissemination of information among the groups. The problem is how to aggregate the assessments and choices made by the different groups to an overall organizational policy. For example, emergency response to an incident at a nuclear power generating facility involves, at present, three groups which are located at different sites, where communication between these groups is verbal with limited use of video [14].

2. MULTIPLE GROUP S IN DECISION MAKING FOR EMERGENCY MANAGEMENT

The different groups in an organization for emergency response are responsible for their unique tasks. In general, one group cannot overrule another group's recommendations or perform its tasks. The decision structures of emergency response organizations might have a single ultimate decision maker, who has the final responsibility for the actions taken in response to an emergency. However, in the process of communication and information exchange, the groups generate several courses of action. Then, the groups together decide on the ranking of the alternative courses of action to present to the decision maker as recommendations.

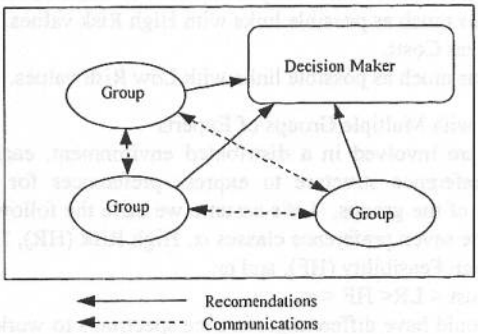

Fig. 1. Multi-Group Emergency Response Organization

A typical emergency response organization for large-scale operations can be divided into four groups consisting of one or multiple experts. The definition of the groups is based on the members' responsibilities in handling an accident as follows:

(1) Operators which execute procedures of the operation under the decision maker's supervision in order to accomplish the objectives of the emergency response.
(2) A recommendation-generating group which generates recommendations for the decision maker to consider. The members of this group have special knowledge of the technologies of the operations and generate recommendations based on their expertise.
(3) A management group whose responsibility is to consider the impact on the organization responsible for the operations.
(4) A decision maker who has the authority and responsibility to make decisions about the operations in an emergency situation. The decision maker will change with the

their preferences, where the sum is based on a lexicographic principle. That is, the preferences within a preference class are added up, but the preference classes remain incommensurable. This means, for example, if high risks are of higher concern than operational costs that there is no amount of operational costs to override concerns for high risks. The preference of an entire course of action is therefore the "sum" of the preferences of all of its activities. The best course of action, among the feasible courses of action, is the one with highest overall preference. Finding the most preferred course of action, or the optimal, is done by an appropriate graph-theoretic algorithm [2].

Two boundary preference classes are used. Activities that do not have any significant risks or costs are assigned to the first class (ω); activities that under no circumstances are to be engaged in are assigned to the second class (α). The resulting five preference classes have the following ordinal relation:

α < High Risks < Costs < Low Risks < ω,

where "<" refers to "less preferred."

For an activity or a course of action to be feasible its overall preference must be higher than a. When the preferences of all activities are assessed, the graph is called a preference graph. Optimal courses of action are determined by an algorithm that operates according to the following hierarchical priorities [2]:

(1) It never recommends an activity with Risks or Costs of value a.
(2) It avoids as much as possible links with High Risk values.
(3) It minimizes Costs.
(4) It avoids as much as possible links with Low Risk values.

2.2. Preference Ranking with Multiple Groups of Experts

When multiple groups are involved in a distributed environment, each group might have available a different preference structure to express preferences for actions, due to the different responsibilities of the groups. Let's assume we have the following meta-preference structure consisting of the seven preference classes α, High Risk (HR), Low Feasibility (LF), Cost, Low Risk (LR), High Feasibility (HF), and ω:

α < HR< LF < Cost < LR< HF < ω.

Then, different groups could have different preference spectrums to work with. such as given in Table 1.

	α	HR	LF	Cost	LR	HF	ω
Group1	*	*			*		*
Group2	*		*			*	*
Group3	*			*			*

Table 1. Responsibility for Assessing Preference Class

The preference spectrum of Group1 is restricted to the preference classes:

α, < HR < LR < ω.

Thus, for Group1, the selection of the preference classes and their order is:

α < HR <- <- < LR <- < ω. which can be written as α < HR < LR < ω.

For the personnel in the Group 2, the preference structure is:

α < - < LF < - < - < HF < ω, which can be written as α < LF < HF < ω.

For Group 3 we might have:

α < Cost < ω

In unexpected deviations from normal conditions, the group members must assess the impact of the RTE on all affected activities using their designated preference spectrum. It can be assumed that the affected activities are presented to the experts one by one.

To illustrate the aggregation of the preferences across the groups, let's consider an example. Let's assume that: Group1 recommends two alternatives with the following preferences: Alt. 1 = [0, 2, -, -, 0, -,0] and Alt. 2 = [0, 2, -, -, 0, -, 0]; Group2 assesses the preferences of the same two alternatives to Alt. 1 = [0, -, 1, -,-,3, 0] and Alt. 2 = [0, -, 1, -,-,4, 0]; and Group 3 assesses the preferences of the same two alternatives to Alt. 1 = [0, -, -, 5,-,-, 0] and Alt. 2 = [0, -, -, 4,-, -, 0], where the preference functions are monotonically decreasing, such that a $5 cost alternative is less preferred than a $4 alternative.

For Group1, the two alternatives have the same preference order, while Group2 prefers Alt. 1. On the other hand, Group3 prefers Alt. 2.

	α	HR	LF	Cost	LR	HF	ϖ
Alt. 1	0	2	1	5	0	3	0
Alt. 2	0	2	1	4	0	4	0

Table 2. Aggregated Assessments.

To aggregate the preferences across the groups, the meta-preference structure is used, which, also, defines the preference relations of all the preference classes used by the different groups: $\alpha < HR < LF < Cost < LR < HF < \varpi$.

The aggregated assessments are shown in Table 2, from which we conclude Alt. 1 > Alt. 2. The decision maker now has vital information both on all the groups' preferences for the alternatives, as well as on the aggregated preferences. However, to implement this proposed decision logic, the groups involved in the decsion making process must be supported in their communication process in real-time. We propose that this be accomplished by the use of multimedia technology.

3. MULTIMEDIA

While research has focused on individual modes of media presentation and Decision Support System, such as voice [11], video conferencing [14;8], graphics [7;16], little attention was given to integrated multimedia and desision support systems [3;1;6;13;12;15;17]. Integrated multimedia presentations can focus on the information the presenters want to convey much more effectively than a single type of media can do. A distributed, integrated multimedia system, with information from dispersed groups of experts, can provide important, relevant information about a situation to appropriate individuals and groups. It also unables all members of a decision making organisation to have the same basis for the understanding of a situation. Therefore, their recommendations can be based on this understanding, avoiding unnecessary information processing.

3.1. Multimedia on Network

It must be recognized that multimedia requires a large amount of space for data, making compression and decompression (codec) technology extremely important to send/receive multimedia data on a computer network. For example, a 640x480 picture with 24 bits of colors (millions of colors) needs 7.4M bits (920 kB); one minute of the same size and color digital movie needs 13.32 G Bits (1.66 GB); and one minute of Compact Disk (CD) quality sound needs 10 MB. An Ethernet local area network (LAN), which is the most popular LAN,

can transfer data at a speed of 10 Mbits per second (bps). A one minute uncompressed digital color movie needs 22 minute to transfer on an Ethernet LAN.
To construct a real-time system on a computer network, codec technology must be employed (Szuprowicz, 1995). Time-dependent dynamic presentation, as opposed to a still media, has the most impact when used in multimedia networking. Time-dependent media includes digital video, audio, live music, and live video.

3.2. QuickTime[2]

QuickTime is based on the concept of standardizing a digital movie on a personal computer (Macinthos, Windows), using common user-interfaces, video/audio codec, file format, and application programming interfaces (API). In addition to video (or time-based data), the standard also applies to still media, such as pictures and graphics, and it integrates time-based data into mainstream applications [9] . including multimedia authoring tools. QuickTime manages video and audio in separate tracks and each track has a timetable, which makes synchronization of video and audio possible.
QuickTime Conference simplifies the exchange of time-based data among computers connected in a computer network, using QuickTime's codec method and its standardization, in addition to Apple's AppleTalk[3] protocol and TCP/IP computer networking. The programming components of QuickTime Conference manage the user-interfaces, conference events, transportation of the conference data, initializing connections, etc. In addition, programmers can exchange their own types of data besides of the conference data, such as video and sound. With these functions vital data can be sent and received for multimedia communications of multiple groups of experts. Because QuickTime Conference can be used on either LAN or TCP/IP, a system can be connected with either LAN or TCP/IP, and the changing of such connections is easy to acheive [10]. In fact, the QuickTime Conference technology is used to develop this decision support system and to integrate the decision logic for the multi-group emergency management layout.

4. PROTOTYPE SYSTEM AND FUTURE RESEARCH

We have developed a prototype DSS that incorporates the proposed decision logic and multimedia technology for an emergency response organization in a nuclear power generation plant. The prototype system supports and links three sites: the Control Room (CR), the Technical Support Center (TSC), and the Emergency Operation Facility (EOF). These connections allow all the members of the Emergency Response Organization (ERO) to share vital information. The operators and the operational decision maker on duty are located in CR. In TSC the recommendation-generating group is staffed, while the management group stays in EOF.
The connections among these three sites have been established using the QuickTime Conference technology, including video conferencing systems, the capability to exchange command messages, and several other information exchange capabilities. All the multimedia data is contained in one individual workstation and controlled with the command messages via QuickTime Conference linkages. This scheme reduces the amount of computer traffic on the computer network.

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[2]QuickTime is trademark of Apple Computer, Inc.
[3]AppleTalk is trademark of Apple Computer, Inc.

4.1. Functions of the Prototype System

Fig. 2 shows an actual view of the prototype system supporting the Control Room during normal or routine operations, that is, an emergency has not been declared. Thus, communications are not established to any other sites.

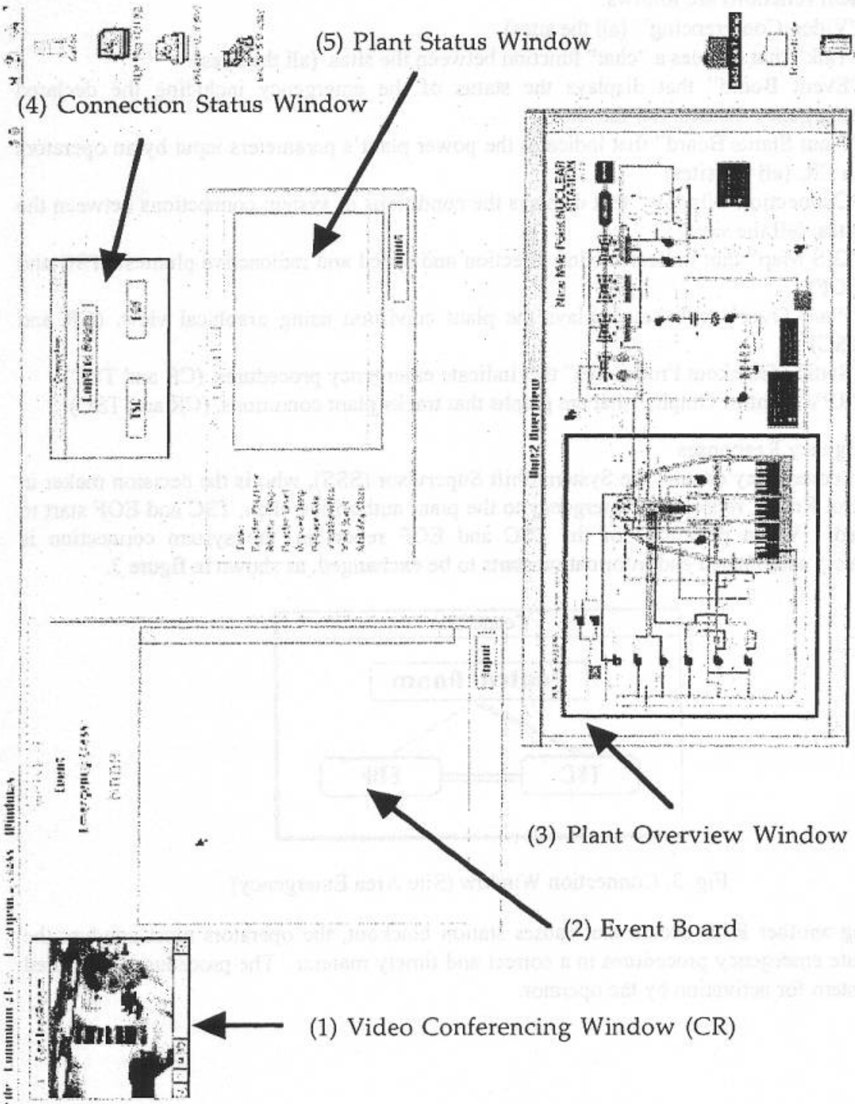

Fig. 2. Prototype of Multi-Group Operational Risk Management Decision Aid

The system was designed for each site, so each site's system has its own functions based on the responsibility of the groups in that site.

4.2. System Functions

The system functions are follows:

(1) "Video Conferencing". (all the sites)
(2) "Talk" that enables a "chat" function between the sites. (all the sites)
(3) "Event Board" that displays the status of the emergency including the declared emergency classes. (all the sites)
(4) "Plant Status Board" that indicates the power plant's parameters input by an operators in CR. (all the sites)
(5) "Connection Window" that displays the conditions of system connections between the sites. (all the sites)
(6) "GIS Map" that indicates wind direction and speed and radioactive plumes. (TSC and EOF)
(7) "Plant Overview" that displays the plant condition using graphical view. (CR and TSC)
(8) "Station Blackout Procedures" that indicate emergency procedures. (CR and TSC)
(9) "RPV Control Graphs" that are graphs that tracks plant conditions. (CR and TSC)

4.3 Emergency Responses

When an emergency occurs, the System Shift Supervisor (SSS), who is the decision maker in the Control Room, reports the emergency to the plant authorities; then, TSC and EOF start to be staffed. When personnel of the TSC and EOF report in, the system connection is immediately established and information starts to be exchanged, as shown in figure 3.

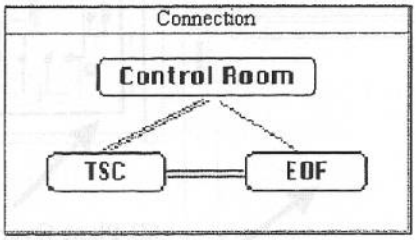

Fig. 3. Connection Window (Site Area Emergency)

Assuming another RTE occurs that causes station blackout, the operators must conduct the appropriate emergency procedures in a correct and timely manner. The procedures are stored in the system for activation by the operator.

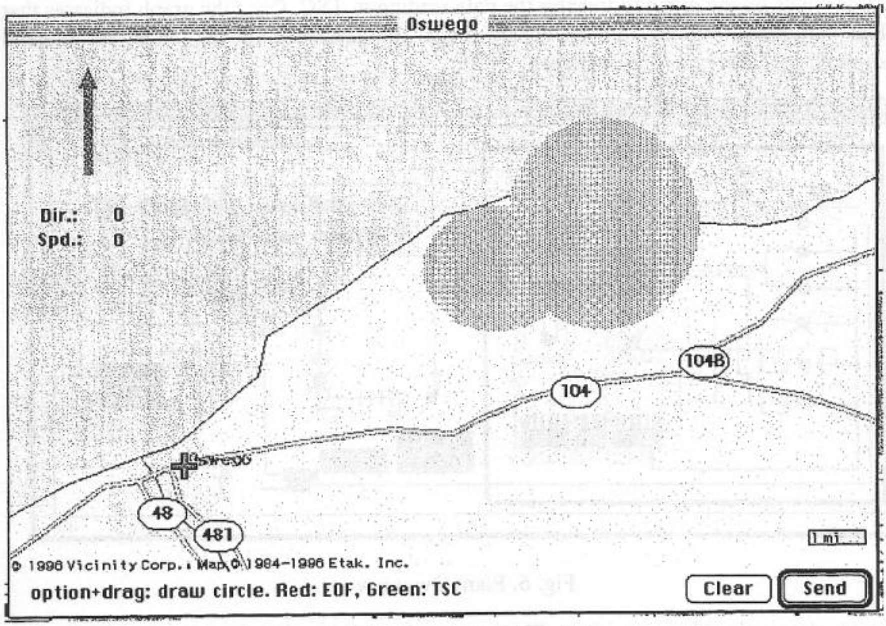

Fig. 4. GIS around the Power Plant

In figure 4, the GIS shows the wind direction and speed that are obtained in CR and transferred to EOF, in order to make recommendations for evacuation of the plant or surrounding community. Spreading radioactive plumes are calculated at TSC and the information is transferred on to the Geographic Information System display.

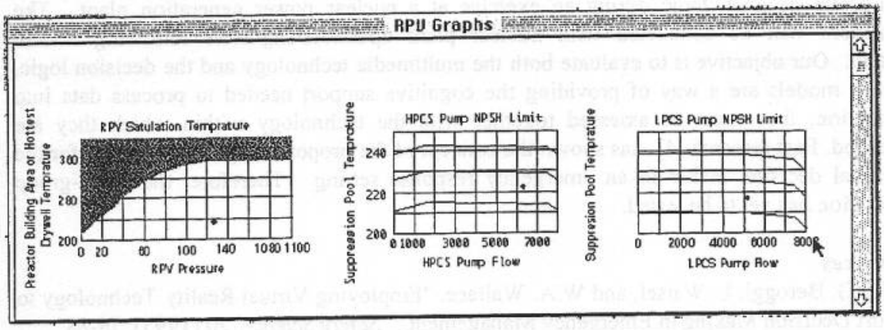

Fig. 5. Reactor Pressure Valves Control Graphs

Reactor Pressure Valves (RPV), as shown in figure 5, control graphs are displayed during the emergency operations. The eight graphs are used in order to monitor the plant condition. The ERO tries to track the plant parameters, to see if it is remaning within its safety range with respect to specified levels. All the data readings for these graphs are obtained in CR and an operator clicks on the graph to transfer the data reading to TSC. Once the graph indicates that a plant parameter is going into an unsafe range, the personnel in TSC must recommend appropriate procedures for the operators.

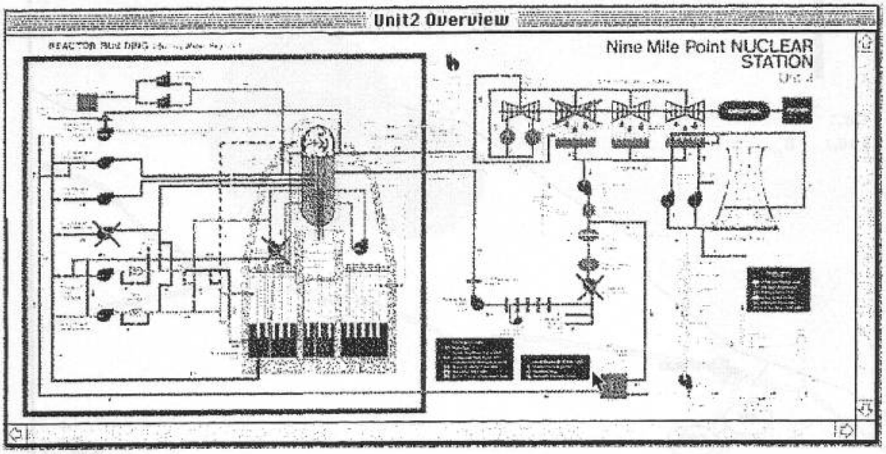

Fig. 6. Plant Overview

Figure 6 shows the plant overview. The status of pumps and valves are displayed on a graphical view. If the ERO finds a pump is malfunctioning, the information is transferred on this view by clicking on the equipment. A cross is shown when some part of the equipment is malfunctioning.

4.4. Future Research

Our current work includes the development of an experimental assessment of the proposed multi-group decision logic during an exercise at a nuclear power generation plant. The experiment will be conducted with nuclear plant operators/engineers following a drill scenario. Our objective is to evaluate both the multimedia technology and the decision logic. Because models are a way of providing the cognitive support needed to process data into information, they must be assessed together with the technology within which they are embedded. Past research [4] has shown the concept of the proposed logic to be useful for the individual decision maker in an emergency response setting. Therefore, the multi-group formulation has yet to be tested.

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