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## Cognitive Learning From Computer-based Information Systems By Incorporating Knowledge Construction Interventions

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COGNITIVE LEARNING FROM COMPUTER-BASED INFORMATION  
SYSTEMS BY INCORPORATING KNOWLEDGE CONSTRUCTION  
INTERVENTIONS

by

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M.S. University of Central Florida, 1998

B.S. King Abdulaziz University, 1993

A dissertation submitted in partial fulfillment of the requirements  
for the degree of Doctor of Philosophy  
in the Department of Industrial Engineering and Management Systems  
in the College of Engineering and Computer Science  
at the University of Central Florida  
Orlando, Florida

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2007

Major Professor: Kent Williams

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## **ABSTRACT**

The aim of the present study was to develop and empirically evaluate different categories of instructional activities, which stimulate the generation and construction of knowledge on the part of an individual student. These generative activities are primed by prompts or scaffolds, which can easily be inserted into specific curriculum addressing any domain of knowledge.

To assess the manner in which the knowledge construction interventions influence the learning outcomes from computerized information systems, we have developed an online computer-based information system that describes the functions and mechanisms associated with the bus system of the US army Abrams M1A2 tank. Seven versions of this interactive instructional computer system were developed for this research; the type of prompt was manipulated among the seven experimental conditions. The seven experimental conditions were control, sentence completion, sentence generation, system provided questions, self-generated questions and answers, system provided advanced organizers, and generated advanced organizers.

The results from this study provided strong evidence that the integration of knowledge construction interventions within the curriculum material have improved understanding of the curriculum content and reasoning about such content over and above the mere presentation and study of the curriculum. The research also delineated a practical way on how to incorporate and operationally integrate the knowledge construction interventions within computer-based information systems.

This dissertation is dedicated to the memory of my father, Ahmed Wazzan, who through his love and encouragement has created my views toward life and learning.

To my wife, Solafah Kadi, you are my inspiration. Your love, understanding, and patience have been instrumental in finishing this work.

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## CHAPTER 1: INTRODUCTION

Humankind has long sought a perfect mechanical person; one who has all the knowledge, skills and abilities of a human, with none of the frailties. Although technology has not yet been able to deliver such a device, it has been able to deliver software systems that can act as a teacher for people. Such information systems exist in desktop computers, training simulations, as well as web-based instruction. Intelligent Tutoring Systems (ITS), an excellent representative example of such systems, provide instruction to students in a manner similar to what human tutors do (Regian, 1991). Intelligent tutoring systems utilize a diverse set of knowledge and inference routines to “compose instructional interactions dynamically, making decisions by reference to the knowledge with which they have been provided” (Wenger, 1987). Intelligent tutors, such as the Algebra tutor (Anderson, Corbett, Koedinger, & Pelletier, 1995), have shown dramatic student achievement gains relative to control classes: 15-25% better on standardized tests of basic skills and 50-100% better on assessments of problem solving and correct representation of problems (PACT, 2002).

Generally, the effectiveness of tutoring as a way of delivering instruction, is well established. Table (1) shows three different kinds of tutoring compared to traditional classroom instruction. Normal human one-to-one tutors, who have moderate knowledge about the domain and limited experience in tutoring, have shown to be more effective than traditional classroom instruction by 0.4 standard deviations. Intelligent tutors, such



as Anderson's et al. (1995) geometry tutor, are better than classroom instruction by 1.0 standard deviation. Accomplished human tutors, demonstrated by a high level grasp of domain knowledge and tutoring experience, are 2.3 standard deviations better than the traditional classroom setting.

Table 1.

Effectiveness of Different Tutoring Approaches

<b>Tutoring Agent</b>	<b>S.D. Improvement over Classroom</b>	<b>Study</b>
Human Tutors	0.4	(Cohen, Kulik, & Kulik, 1982), (Graesser, Person, & Magliano, 1995), (Chi, Siler, Jeong, Yamauchi, Hausmann, 2001)
Cognitive ITS	1.0	(Anderson et al., 1995), (Koedinger et al., 1997)
Accomplished Human Tutors	2.3	(Bloom, 1984), (Kulik & Kulik, 1991)

As indicated by the above research, there is still a gap to bridge between the effectiveness of the best human tutors and intelligent tutoring systems.

A key aspect of human tutoring is the pre-planning of tutoring activities by tutors in terms of what to teach the student and how to teach him/her (Reigeluth, 1983). What to teach is concerned primarily with the design of curriculum (i.e. the content of instruction to be taught). Normally, human tutors have an amount of "knowledge" to be disseminated to students. An example of what to teach can be seen in any course syllabus

of a college class, which includes material to be covered, textbook(s), and any supplemental material(s). How to teach is the way instruction is supplied (i.e. appropriate method of instructional interventions and feedback). Human tutors may elect to correct the student immediately, prompt the student to elaborate, give the student a hint towards the correct answer, and so forth. The education field of Instructional Design Theory (IDT) provides a wide variety of teaching strategies that may be employed by tutors. How effective these instructional strategies are, constitutes a major research question.

In comparison to human tutoring, computer-based instructional systems primarily focus on the content of instruction. These computer tutors do not employ instructional strategies that have been identified by educational research (Rajan, Craig, Gholson, Person, & Graesser, 2001). Many computer tutors deliver instruction in a “one-way” fashion while some, like intelligent tutors based upon cognitive learning theory, provide a limited type of intervention in the form of immediate feedback that is adapted to the specific difficulties on the part of differing students (Anderson, 1993). One of the purposes of this study is to develop and assess the effect of integrating appropriate instructional strategies and interventions within computer-based instructional tutoring systems in a practical and cost-effective manner. In particular, a growing body of research has indicated that prompting students to generate and construct their own knowledge (by answering elaborative questioning for instance) will have a prominent effect on learning and enhance student performance over and above the mere presentation of content (e.g., King, 1992a; Chi, De Leeuw, Chiu, & Lavancher, 1994; Wong, Lawson, & Keeves, 2002)

There is, however, little research showing that incorporating appropriate knowledge generating strategies will improve learning from machine tutors. Hausmann and Chi (2002) studied the effect of using prompted self-explanation, an elaborative strategy found to be a successful way to improve learning from human tutors (Chi et al., 2001; Rosenshine, Meister, and Chapman, 1996). They used a simple computer program to prompt students to type answers to questions such as “could you elaborate more on what you just said?” The study found that students using computer prompting performed as effectively as students using human prompting (control group). Alevan & Koedinger (2002) used Anderson’s (1995) Geometry tutor to study the effect of adding a simple format for self-explanations. Students explained their problem-solving steps by selecting from a menu the name of the problem-solving principle that justifies the step taken. They found that students who explained their solution steps learned with greater understanding than students who did not explain their work. Greater understanding was measured by the ability of a student to explain and justify their answers in a manner consistent with geometry theorems and definitions.

The above two studies indicate that incorporating instructional strategies into practice using computer tutors can have a positive effect on learning. The education field of instructional design theory offers many more instructional strategies that prompt students to generate and construct their own knowledge, which could have great potential for improving the outcome of tutoring. There are no studies that have attempted to compare the effectiveness of different constructive strategies, such as the use of analogies, summarizing, etc, in computer-based instructional information systems.

## **Objective**

This research is an attempt to integrate a wide variety of theories from many fields with the ultimate goal of improving the instructional capabilities of computer-based information tutoring systems. The research is intended to pave the path for more research toward integrating instructional strategies into computer information tutoring systems. Though effective, present intelligent tutoring systems require considerable resources to build and are very costly. In this research, we are looking at innovative, easy to implement ways to improve the effectiveness of these systems that can be easily implemented with minimal cost.

The main objective of this study is to develop and empirically evaluate different categories of instructional activities, which stimulate the generation and construction of knowledge on the part of an individual student. These generative activities are primed by prompts or scaffolds, which can easily be inserted into specific curriculum addressing any domain of knowledge. The integration of these activities into the curriculum material are hypothesized to improve understanding of the curriculum content and reasoning about such content over and above the mere presentation and study of the curriculum. The activities must be generic such that they may be readily implemented into computerized instructional systems at little or no additional cost in terms of time and programming. In particular, we will look at the effect of “adding” instructional strategies that help students generate and construct their own understanding of the materials into computer-based instructional information systems. A review of instructional design theories and

applications may provide insight into how these knowledge construction strategies could be used to enhance the use of computer-based instructional information systems.

The potential for applying this research is broad. It can be used to enhance any computer-based instructional information system delivered by various information system technologies such as desktop computers, training simulators, as well as web-based instruction.

The implications of this work will stimulate designers and developers of computerized information systems to create far more effective and efficient systems. The ultimate outcome of this research is to enhance the ability of computerized tutoring systems to match, or hopefully, exceed the performance of accomplished human tutors.

Chapter 2 of this dissertation presents a comprehensive review of the current state of the knowledge construction research and the human learning process.

## **CHAPTER 2: BACKGROUND LITERATURE REVIEW**

### **Instructional Design**

The Definition and Terminology Committee of the Association for Educational Communications and Technology (AECT) in the United States has been responsible for defining the field of educational technology since 1963: "Instructional Technology is the theory and practice of design, development, utilization, management and evaluation of processes and resources for learning" (Seels and Richey 1994). Instructional Design (ID) is an integral part of instructional technology and can be defined as "the systematic development of instructional specifications using learning and instructional theory to ensure the quality of instruction. It is the entire process of analysis of learning needs and goals and the development of a delivery system to meet those needs. It includes development of instructional materials and activities and evaluation of instruction and learner activities" (Alessi and Trollip, 1991). Spector, Polson, & Muraida (1997) refers to instructional design as the structuring of the learning environment for the purpose of facilitating learning or improving learning effectiveness. Ely (1996) defines the term instructional design as that used by professionals who work with direct applications of technology in teaching and learning. Reigeluth (1999) identified instructional design theory as "a theory that offers explicit guidance on how to better help people learn and develop." The specific types of learning and development may include cognitive,

emotional, social, physical, and spiritual development. Instructional theory describes a variety of methods of instruction (different ways of facilitating human learning and development) and when to use--and not use--each of those methods.

### **Movement Toward Knowledge Construction**

The recent digital fusions, the merger of computer, communication, and information technologies, have made it necessary to evaluate instructional design and methods. Reigeluth (1996, 1997) asserts that the most significant issue in instructional theory at present is the need for a new paradigm. Richey (1997) provides insights about the most recent "agendas" that are likely to have a powerful impact on the directions that instructional theorists pursue in the search for a new paradigm, such as: constructivism, cognitivism, problem-based learning, collaborative learning, hypermedia/multimedia performance technology, electronic performance support systems, systematic thinking, and computer-based learning. Her argument is that the "general social and intellectual climate of the times" influences what ideas reach agenda status. In keeping with Richey's (1997) theory of agendas, Reigeluth (1996, 1997) believes that a powerful factor prompting the need for changes in instructional design theory is the major shift contemporary society is undergoing from the industrial age to the information age. Reigeluth initiates his argument for a new instructional paradigm by identifying how the needs of the late twentieth century job market revolve around problem-solving,

teamwork, communication, initiative-taking, and diverse perspectives. He questions whether present systems of education and training can meet those needs by merely changing the content of what is taught, or whether changes that are more fundamental are necessary. He argues that the current paradigm of education and training based on standardization, conformity and compliance, is geared to suit the mass-production of industrial age manufacturing; which he believes needs to change to a paradigm based on customization, diversity and initiative, to suit the needs of the information-age economy. Reigeluth (1996,1997) stresses that the new paradigm should offer guidelines for the design of learning environments that provide appropriate combinations of challenge and guidance, empowerment and support, self-direction and structure. The new approach should result in designs that allow learners to make more decisions about their instructional methods by allowing them to choose from sound alternative approaches. A process that would be facilitated by the use of computer systems (Reigeluth, 1996; Reigeluth, 1997).

In sum, there is a new movement in the field of education that is encouraging learners to be more active in their learning process, trying to take advantage of learning strategies that have proven to be effective such as, being constructive while learning, developing meaningful understanding of the information, and advocating more use of computer-based information systems. In the following sections, we will define how knowledge is represented in the mind and relate that to the learning process and how to facilitate developing a deep level of understanding among learners.



## **Knowledge Representation**

Two types of knowledge are believed to represent memory of skill: declarative knowledge and procedural knowledge (Anderson & Lebiere, 1998). Declarative knowledge is factual information that a person knows and can report (Anderson & Schunn, 2000). Declarative knowledge represents the verbal rules, facts, or ideas within domain of knowledge. Declarative knowledge is composed of small groups of information elements called chunks. For example, “a fish lives in water and uses its fin to move around” is a particular fact that would be stored as declarative knowledge. It can be acquired through perception, instruction, or reading. The knowledge is assumed to form a semantic network with links connecting concepts (Anderson, 1983). In the example of fish, the concept “fish” would exist as a node, which would be linked to attributes such as “lives in water” and “has fins.” The concept could then be linked to other concepts, such as “water creatures,” which would be linked to an additional set of attributes. It is the interconnections between the nodes that give concepts meaning (Jonassen, Beissner, & Yacci, 1993).

Procedural knowledge, on the other hand, corresponds to the use and application of declarative knowledge, in other words, how to do a particular task. Jonassen et al., (1993) described procedural knowledge as “the interrelating of declarative knowledge into patterns that represent mental performance.” For instance, problem solving represents an activity that would require the use of procedural knowledge. Learners using procedural knowledge contact and interrelate relevant declarative knowledge and use that knowledge to perform the required action. Procedural knowledge is represented by a

large number of rule-like (IF-THEN format) units called production rules (Anderson & Lebiere, 1998). Production rules make up the skills acquired through practice. They are the basic units of knowledge for performing a problem solving activity. Since procedural knowledge is rule-based, it requires cognitive activities that are more performance-oriented and adhere to specific rules (Anderson, 1983). When a production rule's conditions are met (the IF part), an action is executed (the THEN part).

Anderson & Lebiere (1998) agree that acquiring procedural knowledge depends primarily on the number of opportunities a learner has to use these production rules (i.e. the more a student practices using production rules, the more he will learn). This vision, however, does not account for the effect of using instructional strategies that have shown to enhance student's learning and enable them to achieve deep understanding of the material over and above mere practice.

### **Types of Learning**

Two general types of learning have been found to be common among learners: surface-level learning (shallow or reproductive learning) and deep-level learning (meaningful understanding) (Marton, Hounsell, & Entwistle, 1984; Entwistle & Entwistle, 1992; Ausubel, 2000). In surface-level learning, students tend to concentrate on memorizing declarative knowledge (discrete facts) without thoughtful understanding of the relationships between these facts. Deep-level learning, conversely, focuses on organizing and connecting knowledge. This organized knowledge is thought to lead to a

more meaningful understanding of the material. Learning strategies are thought to help learners achieve a deep level of learning by guiding their thought and comprehension towards being more organized and connected.

Deep-level learning can be realized by proper organization of knowledge, not by mere accumulation of knowledge. Mayer (1984, 1987, 1996, 1999) described three cognitive processes that are thought to aid the construction of meaningful knowledge structures. The three processes are selection, organizing, and integrating. The selection process involves focusing one's attention to relevant information and brings it to working memory for further manipulation. The organizing process is very important to the learning process since it creates internal connections between selected information. The process is responsible for building information that is coherent and whole. The final process, integrating, is supposed to connect newly acquired information to related organized knowledge, which already exists in long-term memory. Learning strategies offer different avenues that could help learners to organize and integrate new knowledge.

## Learning Strategies

There is ample evidence from research indicating that proper and effective use of learning strategies can enhance the performance in academic settings (e.g. Rosenshine, Meister, and Chapman, 1996; Pressley & McCormick, 1995; Zimmerman & Schunk, 2001; Schunk & Zimmerman, 1994). Mayer (1984, 1987, 1996, 1999) asserted that effective and ineffective learning experiences lie in the learning strategies that an instructor or tutor employs to guide cognitive processing of the material to be learned. Mayer suggested that students could steer their learning processes to be more efficient and effective by employing different learning strategies. Effective learners use strategies that effectively guide cognitive processing.

Weinstein and Mayer (1986) proposed a helpful taxonomy of cognitive strategies students use to encode, store, organize, and retrieve knowledge. These strategies are classified into three general classes: rehearsal, organization, and elaboration. Marton et al. (1984) indicated that a deeper level of understanding could be achieved by employing elaboration and organizational strategies rather than the rehearsal strategies.

In the rehearsal strategy, learners are encouraged to repeat material, take selective verbatim notes, underline important material, copy material, and recite material. In agreement with Marton et al. (1984), Weinstein & Mayer (1986) found that when students were asked to recite the material being said, they remembered less facts and conceptual information and scored less on a passage-related, creative problem solving task, than the control group who were asked to use their regular learning strategies.

Rehearsal strategies are not as effective as organization and elaboration strategies and could be responsible for shallow types of learning.

Organization strategies involve identifying important information, organizing the information in a meaningful way, and setting priorities pertaining to what information should be learned. Organizational strategies are used mainly with expository text to retain information and connect it to previously acquired knowledge (Ausubel, 2000; Cook & Mayer, 1988). The third and most widely used is the elaboration strategy. The elaboration strategy is thought to assist students in building internal associations between new and old stored knowledge, and hence, aid the knowledge construction process. Elaboration research has received widespread attention. In the next section, we will present an overview of the elaboration theory, followed by detailed discussion of strategies presented by the theory.

### **Overview of the Elaboration Theory of Instruction**

The Elaboration Theory is an attempt to integrate much of the instructional design research into a comprehensive set of macro-level models that would greatly improve the way instruction is designed. It is primarily concerned with the sequencing of ideas as opposed to the individual ideas themselves and the examples relating to those ideas (Reigeluth & Stein, 1983; Reigeluth, 1997; Reigeluth et al., 1980). Specifically, sequencing in this case relates to fundamental and representational ideas, or core principles, which are presented first, that then lead to specifics. These ideas are called

epitomes in elaboration theory; Figure 1 presents an epitome for an introductory course in economics (Reigeluth, 1983).

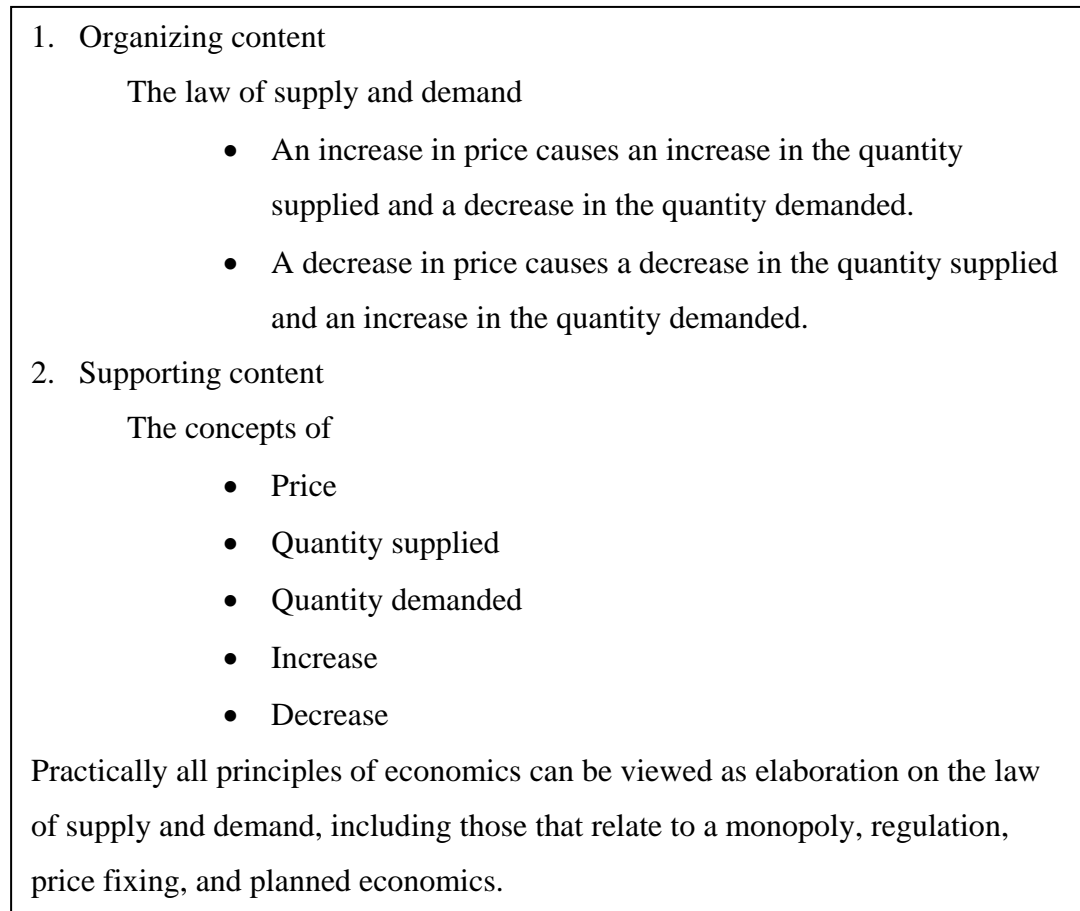


Figure 1. Content for an Epitome for a Course in Economics

The epitome serves as a foundation from which more specific information may be developed.

The theory can be described by an analogy to a zoom lens (Reigeluth & Stein, 1983). At the beginning, the subject, when shot by the wide-angle lens, is general and

fundamental. As we zoom in with the lens however, we start to develop details and can pick up specifics about our subject matter. We can also observe the relationships between our wide-angle subject and those details. This principle as applied to elaboration theory is called a "cognitive zoom". Before we can zoom though, we must first deal with the broader, core aspects of our subject. Elaboration begins with an overview of the simplest and most fundamental ideas of the domain. It is important to note that certain prerequisites exist for this overview and if the students do not have these prerequisites, then the teacher must provide it.

The macro level of instruction in accordance with elaboration theory deals with four problem areas that are referred to as the four S's in the theory: selection, sequencing, synthesizing and summarizing of the subject-matter content. Elaboration theory tries to prescribe optimal methods for all four areas by employing seven components. The seven components in elaboration theory (Reigeluth, 1987) are:

1. An elaborative sequence for the main structure of a course.
2. A variety of prescriptions for sequencing within individual lessons of a course.
3. Summarizers.
4. Synthesizers.
5. Analogies.
6. Cognitive strategy activators, and
7. A learner-control format.

The seven components are described next.

The first component is the construction or development of an Elaborative Sequence. This simple to complex procedure can take many forms: an overview, an advance organizer, web learning, and spiral curriculum are examples. Web learning uses an initial broad conceptual outline followed by progressively more detailed and specific information, it is like a web which has a central start point (the outline) and expands in many directions aiming at teaching conceptual relationships (Norman, 1973). Spiral curriculum sequencing, on the other hand, entails teaching simplified ideas initially and then cycling back to teach the same ideas again in great detail, like an ever widening and rising spiral (Bruner, 1960). This sequence is one in which the general ideas epitomize rather than summarize, and the epitomizing is done on the basis of a single type of content. Epitomes must be ideas that are presented at a concrete, meaningful, application level. Epitomes are preformed with three types of content: concepts, procedures or principles. Concepts are certain sets of objects, events or symbols that have certain common characteristics. Procedures are sets of actions intended to achieve an end. Principles illustrate changes, generally denoting cause and effect. One of these types of content is chosen as the most important one to achieve the goals of a lesson or course. The sequence is then said to have an organization based on this content (conceptual, procedural, and theoretical organizations). Epitomizing is structured as follows: one type of content is chosen, then all the organizing content in the course is listed, after which the most basic and fundamental ideas are selected and presented at the application level rather than the abstract level (English & Reigeluth, 1996).



From the epitome, we can elaborate upon the organizing content presented therein. This is the first level of elaboration. The second level elaborates upon the organizing content in the first level. The process continues in the same way. The relationships that result between the levels are organized according to content including the prerequisites, which are conceptual, procedural, theoretical and learning-prerequisite relationships. At each level, an expanded epitome is used to create a means to elaborate upon the next level. Sequencing of content is done according to type:

- Concepts are approached with abstract breadth in a summary but by epitomizing, we deal in terms of narrow application in which a few general and inclusive concepts are taught in the overview at the application level.
- Procedures are more varied in approach in that they can be sequenced according to the order of steps. Forward and backward chaining in which the steps are taught either in the order in which they are performed or the reverse order (backwards), hierarchical sequencing in which all the major sub-steps are taught separately before integrating them into a step in the sequence, general-to-detailed sequencing based on summarizing and, simple-to-complex sequencing based on epitomizing by presenting the shortest paths (procedures) with each successive path becoming more complex.

- Principles are dealt with in the same way as concepts, by epitomizing (with a few simple, fundamental principles taught at the application level).

Moreover, there are two types of sequencing strategies in the elaboration theory (Reigeluth, 1999; Bruner, 1960):

1. Topical Sequencing: In which a given topic is taught in the desired depth before moving to next topic on the agenda. The advantages of such a strategy include improving student concentration and utilizing all available resources to teach that topic.
2. Spiral Sequencing: The learner is taught a given topic gradually in several passes, while visiting other topics in the same pass. This strategy might be useful in teaching interrelationships among topics.

The next component of elaboration theory is a Learning-Prerequisite Sequence. This is necessary to determine if the learners have the essential knowledge that will allow them to learn the specific content on hand. If the necessary knowledge is not present, it must be provided.

Summarization is the third component, which systematically reviews what has already been learned. The use of a summarizer is necessary. A summarizer provides a concise statement of each idea as well as a reference example and diagnostic items for said idea. Two types of summarizers are used: internal, where the summary comes at the

end of the lesson and deals specifically with the content of that lesson, and within-set, which deals with all that has been learned so far in a particular set of lessons. This can include other lessons that coordinate with that lesson.

The fourth component is a synthesizer. The purpose of this component is to integrate and interrelate the ideas taught thus far. The intent is to facilitate deep understanding, meaningfulness and retention in regards to the content area.

Analogy is the next component. Analogy is the use of a familiar idea or concept to introduce or define a new idea or concept. Analogies aid the teacher in reaching the learner's field of experience.

A Cognitive-Strategy Activator allows the teacher to present the learner with a situation in which cognitive processes and skills are put into practice. Some of the processes aimed for are the creation of mental images and the identification of analogies. There are two categories of cognitive-strategy activators: imbedded, as with pictures, diagrams, analogies and other elements that force the learner to interact with the sequence and content, and detached, which causes the learner to employ a previously acquired cognitive skill.

Finally, Learner Control, according to Reigeluth's associate Merrill (1980), deals with the freedom of the learner to control the selection and sequencing of such instructional elements such as content, rate, components (instructional-strategy) and cognitive strategies. The application of the theory as a whole is not the purpose of this study. Our focus, though, is on the teaching intervention strategies provided by the theory and their implications when integrated within computerized tutoring systems.

Elaborative strategies present an excellent opportunity for learners to construct their knowledge about the subject. The construction of knowledge has been shown to have a positive and enduring effect on learners (Chi et al., 2001; Chi et al., 1994; Wong et al., 2002; King, 1992a). The constructing or generating effect of knowledge is discussed next, followed by a detailed discussion of the elaborative strategies.

### **Constructing and Generating Knowledge**

Constructivism is an approach in instructional design that encourages learners to develop their own knowledge by trying to manipulate the material provided to them and make sense of it (Jonassen, 1999). Constructivist learning is based on students' active participation in problem-solving and critical thinking regarding a learning activity that they find relevant and engaging (Mayer, 1999). They are "constructing" their own knowledge by testing ideas and approaches based on their prior knowledge and experience, applying these to a new situation, and integrating the new knowledge gained with pre-existing intellectual constructs (Bruner, 1973). The student is pursuing a problem or activity by applying approaches he or she already knows and integrating those approaches with alternatives presented by other team members, research sources, or current experience. Through trial and error, the student then balances pre-existing views and approaches with new experiences to construct a new level of understanding. Learning is then assessed through performance-based projects rather than through traditional paper and pencil testing. The teacher is a facilitator or coach in the constructivist learning

approach. The teacher guides the student, stimulating and provoking the student's critical thinking, analysis and synthesis throughout the learning process (Mayer, 1996). The teacher is also a co-learner.

The theory of constructivism has reached its current state by incorporating developments from many scientists like Jean Piaget, Seymour Papert, Jerome Bruner, Lev Vygotsky, John Dewey, and many more. Two of the recent additions to the theoretical framework are the works presented by Mayer (1999) and Jonassen (1999), which deal with designing instruction for constructivist learning and designing constructivist learning environments, respectively. The work of these researchers is presented in the following pages.

Mayer's (1999, 1996) theory focuses on human cognitive processing and guides the design of instruction according to the way information flows inside the head. The theory is intended to aid student retention as well as the transfer of knowledge by activating three cognitive processes in the learner's mind during interaction. These processes are selecting relevant information, organizing incoming information, and integrating incoming information with existing knowledge. He refers to this analysis as the SOI model that highlights the three cognitive processes important for constructivist learning: Selecting, Organizing, and Integrating. The three elements of the SOI model are listed next.

1. Selection of relevant information by
  - a. Providing a summary.

- b. Highlighting key information using: headings, italics, boldface, font size, bullets, arrows, icons, underlining, margin notes, repetition, white space, and captions.
  - c. Using instructional objectives and/or adjunct questions.
  - d. Being concise by trying to eliminate irrelevant information.
2. Organize information for the learner using:
- a. Outlines.
  - b. Headings.
  - c. Pointer or signal words.
  - d. Graphic representations.
  - e. Structure text for:
    - i. Comparison/contrast structure.
    - ii. Classification structure.
    - iii. Enumeration or parts structure.
    - iv. Cause/effect structure.
3. Integrate information by applying:
- a. Advance organizers.
  - b. Animation with narration.
  - c. Worked-out examples.
  - d. Elaborative questions.
  - e. Illustrations with captions.

The theory is intended to foster knowledge construction by directing student

learning with appropriate instructional prescriptions. The theory works best with textbook-based learning, lectures, and multimedia environments.

Jonassen (1999) presents a theory that fosters problem solving and conceptual development by employing constructivist-learning environments. The theory is suitable for learning involving ill-defined or ill-structured problems. It is centered on a problem of interest to be solved or mastered by the learner and instruction is given as experiences, which help knowledge construction. The theory is illustrated in systematic points as follows:

1. Select an appropriate problem, or challenge, for the learner to focus on. The problem should be:
  - a. Interesting, relevant, and engaging, to foster learner ownership.
  - b. Ill-defined or ill-structured.
  - c. Authentic and representative of what learners do.
  - d. Its design should address its context, representation, and manipulation space.
2. Present related cases or worked examples to engage case-based reasoning and enhance cognitive flexibility.
3. Provide learner-selectable information just-in-time. Also, information relevant to the problem should be easily available and accessible.
4. Provide cognitive tools that scaffold required skills including:
  - a. Problem representation tools.
  - b. Knowledge modeling tools.

- c. Performance support tools, and
  - d. Information gathering tools.
5. Provide conversation and collaboration tools to support discourse communities, knowledge building communities, and/or communities of learners.
  6. Provide social and contextual support for the learning environment.

Additional instructional activities are provided by the theory to enhance the learning experience. These include: modeling the performance, coaching during the course of learning, and regulating task difficulties. The theory presents a major framework that integrates many aspects of constructivist learning work into one sound theory.

In addition to the above research, several researchers have attempted to enlighten the effect of what is known as the “construction” or the “generation” way of learning, starting with the early work of Wittrock (1974). The current emphasis of constructivism is on the encouragement of “more active and self-directed learning on the part of the student” (Chi et al., 2001). Students will remember materials they generated themselves better than materials generated by others. This constructive, or generative, effect has been seen in both laboratory and natural settings (Foos, Mora, & Tkacz, 1994).

Research on the construction effect has indicated that the learner’s prior knowledge may be an important factor in the effectiveness of generative strategies. The effect may be explained in terms of schema theory. Schema theory is discussed next.



## **Schema Theory**

A schema is a student's organized knowledge of the world. According to schema theory, a schema provides much of the basis for comprehending, learning, and remembering ideas (Anderson, 1994). Rumelhart (1980) stated that, "Schemata are employed in the process of interpreting sensory data (which could be any type of new sensory information), in retrieving information from memory, in organizing actions, in determining goals and sub-goals, in allocating resources, and, generally, in guiding the flow of processing in the system." In that regard, schema theory would advocate that the construction effect take place because students who have a well-developed schema for any given subject would benefit from drawing the elaboration from their own schema, hence activating their own prior knowledge (Anderson, 1994). According to Wong (1985), it is necessary to teach students "prior-knowledge-activating questions" in order to take full advantage of stored schema knowledge. We plan to activate prior knowledge on student's behalf by incorporating elaborative strategies such as self questioning, forming analogies, etc. According to schema theory, students who can effectively relate new information to prior knowledge will be more likely to remember that content in the future. Appropriate elaboration strategies are thought to provide much help in that regard. This is also consistent with Ausubel's (2000) notion of meaningful learning.

## **Elaboration Strategies**

As described by the theory, elaboration strategies help learners make learning material more meaningful by expanding on the presented information, activating previously stored information, and integrating new information with stored knowledge. Elaboration strategies include generative summarizing, revising, forming analogies, questioning, advance organizers, hypothesizing, justifying, criticizing, reflecting, and predicting (Reigeluth, 1983; Royer & Cable, 1976; King, 1992; Scardamalia & Bereiter, 1983; Rosenshine et al., 1996; Chi et al., 2001).

Elaboration strategies have consistently been found to enhance the outcomes of learning in empirical studies (e.g., Pressley, Symons, McDaniel, & Snyder, 1988; Woloshyn, Willoughby, Wood, & Pressley, 1990). It should be noted that all of this research was performed without the assistance of computerized information systems. In essence, it was performed via the regular classroom setting by providing students with a paragraph(s) containing text on material to be learned. Proper training for using the designated elaboration intervention(s) is then given to a test group and the outcome is compared to a control group using usual performance evaluation methods such as written tests, multiple choice questions, etc. This led us to the main purpose of this research, to find out whether these elaborative strategies are going to be as effective when used within computerized information systems. In other words, with the absence of the interactions between the human tutor and the learner, would these interventions be as effective in computer-based information systems as they might have been demonstrated in traditional student-tutor settings. Moreover, it would be very beneficial to detect which of the

elaboration strategies are the most effective and appropriate to be implemented in computerized information systems.

A detailed discussion on elaborative strategies, their effectiveness, and the way they are implemented in tutoring settings is discussed in the following chapter. In chapter 3, we will describe how some of these elaborative strategies could be incorporated into computer based instructional systems.

### **Generative Summarizing**

Summary writing is performed after reading a text, or part of a text, where the essentials of the text are summarized in one or two phrases in the student's own words (Brand-Gruwel, Aarnoutse, & Van Den Bos, 1998). In essence, generative summarizing is the activity by which students apply a basic skill, trying to reflect on what he/she has already learned by writing-down representative ideas of their learning experience. A summary should "capture the gist of the piece as well as reduce the material substantially" (King, 1992a). It should be noted that summarizing in the context of this study is different from the conventional form of summary writing, where students simply manipulate and delete text to produce a summary, a standard practice in many text summarizing studies (e.g. Ross & Divesta, 1976; Brown & Day, 1983; Reinhart, Stahl, & Erickson, 1986).

According to Wittrock & Alesandrini (1990), the summarizing process is knowledge generative where students use their own words and prior experiences to link

different ideas from the text together, using their own expressions and sentences. These novel sentences, which are not presented in the material, make connections between new knowledge and existing knowledge stored in memory. The key aspect of applying this strategy depends on learners using their own words, which allow for automatic knowledge construction since those words are associated with previously stored knowledge and will methodically activate connections and relations between new material and existing knowledge (Wittrock, 1990). Although generative summarizing has been investigated as a strategy for learning from lectures in traditional classroom, as we will present next, generative summarizing has not been investigated as a tool to enhance learning from computer-based information systems.

Another form of generative summarizing is to direct students' attention to important segments of the text by asking them to either complete sentences or generate their own sentences using provided key words (Jacoby, 1978). We believe that this form of summarizing is more conducive to learning since it will force learners to concentrate and generate more connections to key segments of the curriculum. Incorporating the summarizing prompt in this fashion is presented in chapter 3.

Summary writing has been shown to improve learning. For example, in the Wittrock & Alesandrini (1990) study, subjects were assigned to one of three groups: summary, analogy, and a control group. Students in the control group were asked to simply reread each paragraph to control for time. Students in the summary group were asked to read and review a paragraph of text and then write a summary of each paragraph in the space provided in the answer booklet. A summary was depicted as consisting of

one or two sentences that describe the main idea or topic of a paragraph. Students were instructed not to use any terminology from the paragraph, not to copy sentences directly from the passage, and to write their own sentences. Students in the analogy group were instructed to look at each paragraph and to write an analogy relating the content of that text with their prior knowledge or experience. An analogy was depicted as consisting of one or two sentences that relate clearly new ideas discovered in the text with their past knowledge or experience. They found that students in the generative summary group and the analogy group achieved higher score on a text comprehension test than students in the control group. However, no differences were found between the summary and the analogy groups.

Hooper, Sales, & Rysavy (1994) attempted to replicate and extend Wittrock & Alesandrini's work by investigating 111 students working alone and in pairs. They used the same three treatments as Wittrock & Alesandrini did for both the alone and paired groups. In addition to confirming that students in the generative summarizing and analogies groups outperformed students who did not use any strategy, they found that students in the generative summarizing group scored better than students in the analogies group in a posttest achievement exam. Moreover, they found that students working alone performed better than students working in pairs. In agreement with previous research, King (1992b) compared self-questioning, summarizing, and note-talking review for learning from lectures. King found that students in self-questioning and summarizing groups recalled lecture content better than students who reviewed their notes. Although the summarizing group out-performed the self-questioning group on immediate recall

test, the two groups were compatible on a recall test one week later.

In another study by Davis and Hult (1997), they found that 79-college students, who were instructed to write summaries after attending lectures, performed better than a pause group and a control group on a free-recall question immediately following the lecture, as well as on a 12-day posttest. Radmacher and Latosi-Sawin (1995) also compared the exam scores of two college classes, one that used summarizing techniques, and another class that did not (control group). The mean exam score was significantly higher for the summarizing group than for the control group.

The summarizing strategy could be easily implemented in a computer-based instructional system by inserting prompts in various locations of instructional materials where students are directed to write a summary of what he/she had learned. Mapping the above research into computer-based instructional information systems could be accomplished by replacing text written on paper with text provided on computer screen and allowing students to write their generated summaries utilizing the computer keyboard. Obviously, any text editor could be utilized to capture a student's summary.

### **Revising**

Revising own-knowledge is another generative process in which one can map words, symbols, and concepts among different subjects and in doing so make an outline of the material to be learned to form connections between new and existing knowledge (Kiewara, 1989). In conventional classroom setting, revising own knowledge is done

primarily by asking students to go back to their class-notes and try to deeply revise the information contained in them. Research on note taking and methods of reviewing notes has shown to have an enhanced effect on learning (Kiewara, 1989). Though taking notes and revising has shown to improve the learning experience, it is not as effective as summarizing or self-questioning. King (1992b) compared self-questioning, summarizing, and note-taking review for learning from lectures. King found that students in self-questioning and summarizing groups recalled lecture content better than students who reviewed their notes. Although the summarizing group out-performed the self-questioning group on immediate recall, the two groups were compatible on a recall test one week later.

For the purpose of this study, revising one's own-knowledge can be incorporated by devising the computer based instructional system to allow learners to move back and/or forth to revise what he/she has already learned and make sense of it.

### **Forming Analogies**

An analogy (sometimes called a metaphor or a similarity-based reminding) is the partial similarity between two things not otherwise alike, for example, the analogy between a bird and an airplane (Eberts, 1994). Analogies require the establishment of similarity in certain characteristics, relations or properties between quite dissimilar things. In an analogy, information from a familiar domain (the base) is used to understand a novel domain (the target). More specifically, reasoning by analogy entails the

identification of similarities between disparate domains and the transfer of additional information from the familiar base domain to the novel target domain (Gentner, 1983, 1989; Holyoak & Thagard, 1989). Analogy makes possible deduction of properties on the basis of reasoning which is made understandable by reflection of the analogue (Duit, 1991). In teaching, the instructor chooses a concrete situation the student is familiar with and presents new information in terms of how it relates to the old familiar information (Eberts, 1994).

Forbus, Gentner, and Law (1994) identified two types of similarity-based analogies which they sometimes refer to as reminders: surface and structural. Surface similarity is based on “dumb” superficial commonalities. The analogy between a bicycle and a pair of eyeglasses is an example of such surface resemblance. This kind of resemblance does not expose any common “real” properties between the base and the target. Structural reminders, on the other hand, represent much deeper similarity and is based on both structural and surface characteristics. An example of structural analogy is the analogy between the atom and the solar system. The atom is like a miniature solar system: Electrons revolve around a nucleus the way planets orbit the sun. The analogy between electrical current and water flowing in a pipe is another example of surface and structural resemblance.

Forbus et al. (1994) suggested that in order for a student to make an analogy between prior knowledge and some target situation, they should initially access similar (base) information in long-term memory, then create a mapping from the base to the new information (target), and lastly, evaluate the mapping. Hence, the analogical learning



process just described, contains three key stages: access, mapping, and inference (Falkenhainer, Forbus, & Gentner, 1989). Access takes place when the base is retrieved from long-term memory. This may occur spontaneously or via a prompt from an outside source, such as a computer prompt which we intend to use in this research. Whichever the case, once the base has been activated, mapping begins. In the mapping phase, structural and surface similarities between the base and target are recognized and the domains are aligned in terms of the highlighted commonalities (Gentner & Markman, 1997). Alignment and mapping pave the way for the generation of inferences pertaining to the target. The mapping and inference stages outline the core of the analogical reasoning process. The identification of an appropriate mapping is, in particular, a critical prerequisite to useful knowledge transfer (Clement & Gentner, 1991; Gentner, 1989; Halford, 1992; Holyoak & Thagard, 1989). An excellent example of structural mapping is given in Gentner & Toupen (1986) which outlined three rules for a successful mapping process to occur: (1) the attributes of the objects in the base are dropped, (2) relations between objects in the base tend to be mapped across, and (3) systematic higher order of relations are also mapped and isolated relations are discarded. Figure 2 depicts an analogy between the solar system (base) and the hydrogen atom (target), assuming that the learner has sufficient prior knowledge about the solar system that the sun is at the center of the solar system and planets revolve around it.

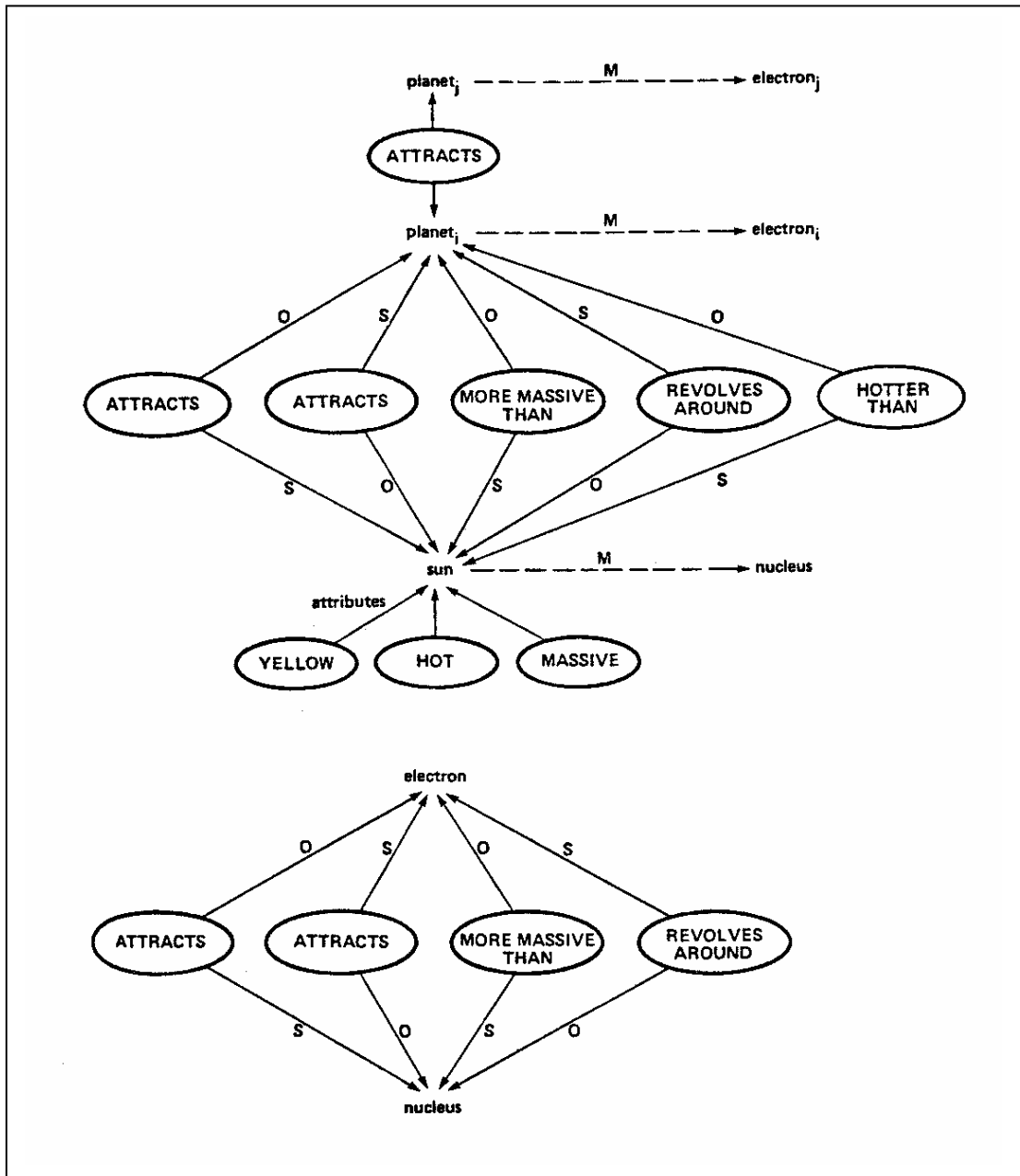


Figure 2. The Analogy between the Solar System and Hydrogen Atom

According to Gentner & Toupen, when learners look at the analogy for the first time they will:

- Establish the object similarities between the solar system (base) and hydrogen atom (target).
- Discard object attributes, such as the sun is yellow.
- Map base relations, such as “the sun is more massive than planet,” to the target domain such as “the nucleus is more massive than the electron.”
- Discard isolated relations such as “the sun is hotter than the planets” and map systematic higher order relations such as “the sun is more massive than planets” and “the smaller object (planet) revolves around the sun.”

According to Hesse (1966), analogies played a key role in the historical development of scientific knowledge. There is enormous research indicating that analogy is an effective strategy for learning. For example, analogies facilitate and improve creative discovery (Holyoak & Thagard, 1995), spelling skills (Nation & Hulme, 1996), solving statistical problems (Bernardo, 2001; Ross, 1987), and mathematical problem solving (Novick & Holyoak, 1991). Analogy, in particular, has been shown to be an effective tool for teaching a conceptual understanding of technology such as learning computer programming (Anderson & Thompson, 1989). Conceptual knowledge helps people create a "big picture" perspective, generalize from the specific, and solve problems in similar or different situations. Examples of the usefulness application of analogies in learning will follow.

Ross (1987) found that giving learners analogical examples to illustrate a probability principle, facilitated their later use of the probability formula to solve other problems. Similar to Ross (1987), Bernardo (2001) conducted a study of 48 high-school students that were taught to use what the author called “analogical problem construction” to learn basic probability and statistics problems. It was hypothesized that letting students construct their own problems, and hence be more actively involved with the material, would allow students to learn more and be able to transfer analogical problem information between source and target problems. Subjects were distributed between a control and experimental group. Subjects in both groups were first asked to study a set of word problems of four different basic statistics problems, see Figure 3 for an example of a problem study sheet, used in the Bernardo (2001) study.

There are 76 books in the Science section of the library, six of which are new. In the History section, there are 120 books, 15 of which are new. The principal randomly picks a book from each of the two sections. What is the probability that the principal picks a new book from both sections?

This is a conjunction problem with independent events. The problem seeks to find out the probability that two unrelated events both occur. There are two events, A and B, that each has a given probability of occurring:  $P(A)$  and  $P(B)$ . The two events are independent because the probability that one occurs is not affected by the occurrence of the other. The probability that both events occur,  $P(A \& B)$ , is the product of the individual probabilities of the two events. The relationship among these different probabilities is summarized in the equation:

$$P(A \& B) = P(A) * P(B)$$

In this problem, the probability that a new book is randomly picked from the Science section of the library can be computed:

$$P(A) = 6 / 76 = 0.078947 \text{ (or about 7.89\%)}$$

The probability that a new book is randomly picked from the History section of the library can also be computed:

$$P(B) = 15 / 120 = 0.125 \text{ (or 12.5\%)}$$

The probability that the principal randomly picks a new book in both sections can then be computed using the equation:

$$P(A \& B) = P(A) * P(B)$$

$$P(A \& B) = 0.078947 * 0.125$$

$$P(A \& B) = 0.0098683$$

So given the equation  $P(A \& B) = P(A) * P(B)$ , we know that the probability that the principal randomly picks a new book from both sections is approximately 0.99%.

Figure 3. An Example of a Study Problem

As illustrated in figure 3, study problems were accompanied with worked-out solutions and descriptions of the relevant principles for solving the problem. Subjects in the experimental group were asked to construct their own analogous problems after they studied each different problem type. The control group subjects were asked to study the principles and the worked-out solutions for the different problem types. After completing

the study phase, both groups were presented with the same test. The test was designed to measure overall transfer from the base to the target. Student solutions were coded as showing complete transfer (1 point), transfer with error (2/3 points), partial transfer (1/3 points), or no transfer (0 points). The mean transfer score for the control group was 0.09 points compared to 0.21 points for the experimental group. The difference between the two means was statistically significant. The author concluded that the outcome of the study showed that students who engaged in analogical problem construction would be better able to notice the elements of the problem structure than students who used regular study techniques.

Analogies could be used to market new products, especially innovative new products that many consumers have not seen before. Paxton, Hibbard, Brunel, and Azar (2002) used analogies to inform customers about what they called “really new products” (RNP) which are novel innovations that are being introduced to the market. Seventy-two graduate students enrolled at a large midwestern business school participated in the study. Subjects were distributed between two treatments: control (no analogy) and experimental (analogy). The control group was given a product description containing basic attributes and benefit information about the product. The experimental group received a product description containing an analogy in addition to the attribute and benefit information. The product used in the study was a personal digital assistant (PDA). The PDA was a joint research project involving Harris Electronics corporation and Seiko corporation and at that time, qualified as an RNP that required both the consumer and the organization to think differently in producing and using the new

product. Subjects were provided with a booklet containing information about the project on the first page. The second page of the booklet contained the product description. For the experimental group, a third page was added and provided study subjects with an analogy between the PDA and a personal secretary. This analogy highlights the fact that, like a personal secretary, a PDA performs many routine tasks for the user. For example, based on the idea that a personal secretary takes dictation from his or her boss, the customer might realize that a PDA possesses a comparable note-taking functionality. In this example, analogy, takes advantage of the similarities between the base (secretary) and target (PDA) using the common features as a basis to generate inferences that would enhance comprehension of the new product. The main outcome of the study found that subjects who engaged in analogical processing of the new product information were more focused in their processing than subjects who processed the same information in the absence of analogy. Furthermore, there was evidence to suggest that analogical processing itself results in the generation of a positive affect.

Analogies can be utilized to teach spelling to children. Research has shown that as children grow older, their utilization of analogies to spell similar words increases. For example, Marsh, Friedman, Welch, & Desberg (1980) asked 7-, 10-, and 16-year-old children to spell nonwords such as zoldier or wength (analogies to soldier and length). They found that 7-year-old children did not use analogies to spell these nonwords. In contrast, 33% of the 10-year-olds and 50% of the 16-year-olds were able to make analogies. In a follow-up study, Marsh, Friedman, Desberg, and Saterdahl (1981) checked the children's ability to spell the base words and still found that the use of

analogy increased developmentally, with the 10-year-olds using an analogical strategy significantly more often than the 7-year-old children do.

Recently, Heywood (2002) called for a shift in way analogies are being used by the scientific community. He argued that the scientific community should shift its attention from “determining the effectiveness of analogy in cognitive transfer from base to target domains towards the recognition of the role of analogy in generating engagement in the learning process.” In such a paradigm, meaning in science for both learner and teacher is derived from discourse. This position could be enforced by the fact that in some domains it is difficult or even impossible to come up with a reasonable and widely agreed upon analogy. In such cases, each student would have his/her personal schema of the situation. Analogies can be incorporated into computer-based instructional systems such that at designated points in the curriculum, students will be prompted to come-up with their own analogy to the material being reviewed instead of providing a particular analogy for the situation. The application of analogy in this way was used by Bernardo (2001) reviewed earlier. Such prompts will come in a question format like “what does this remind you of” or “does this resemble something you are familiar with.” We anticipate that using analogies in this way will activate prior knowledge on the learners’ behalf and will be in agreement with one of the research objectives of finding an effective, yet simple way to implement knowledge construction interventions.



## Questioning

According to Graesser, Baggett, and Williams (1996) question-driven explanatory reasoning presents “one of the fundamental cognitive components that guide human reasoning.” A self-questioning and explaining strategy involves prompting students to “pose and answer their own thought-provoking questions pertaining to the lesson content” (King, 1992a). Using this strategy, students are encouraged to explain to oneself what is going on during the learning experience by asking questions that will help them to understand the new text or material. Scardamalia & Bereiter (1984) called these questions “procedural prompts” that cue learners to perform specific ways of transforming what they are studying or writing. For example, students could use these questions as cues for the retrieval of related information, or for more deep analysis of the new material, or to create connections between different parts of the material.

According to Pressley et al. (1987) and Wood, Pressley, & Winne (1990) self-generated elaborations, like elaborations produced by learners to answer their own questions, are more conducive to learning than elaborations provided by textbook, a teacher, or any other external source. King (1992a) believes that self-made elaborations are more memorable to the student because they are more coherent with a student’s own knowledge and prior experience (i.e. student’s own stored organization of information). These personalized elaborations are easier to process and recall since it is related to prior meaningful knowledge. These elaborations create more links to what is already known and hence provide explicit encoding cues for recall. She also suggested that students

would be more motivated to use their own elaboration than simply memorize others “ready-made” elaborations, and that motivation would improve recall.

Many studies have investigated the use of questioning strategies across a range of curriculum and across levels of education: in writing (e.g. Scardamalia, Bereiter, & Steinbach 1984), in mathematics (e.g. Schoenfeld, 1985), in science (e.g. Chi et. al., 1994; King, 1994), and in reading comprehension (e.g. Andre & Anderson, 1979). Rosenshine et al. (1996) reviewed the outcomes of 26 studies in which students were taught to generate questions and answers to improve comprehension and found that the outcome of this type of training had a small-to-medium effect on comprehension performance where standardized tests were used as outcome measures. The average size of this effect, when quantified using a measure of the standardized difference of means between experimental and control groups known as an effect size (ES), was 0.36.

King (1989, 1991) investigated the effect of what she called a “guided learner-generated questioning strategy” and compared it to three different study strategies: guided peer questioning, unguided small group discussions, and unguided independent review. The guided learner-generated questioning strategy asked students, working alone, to generate their own question and answers, utilizing a list of questions to serve as examples. The guided peer-questioning group employed the same list of questions used by the guided learner-generated questioning group but instead of answering their own questions, they answered peer’s questions. The unguided small group discussions were instructed to talk about the material in a freestyle format. The unguided independent review students were simply instructed to review the material alone and try to make sense

of it. In the first study (King, 1989), 32 college students listened to five classroom lectures containing topics in educational psychology. After each lecture, they reviewed the lecture's content while practicing their respective study strategy. In the guided learner-generated questioning condition, students were presented with a group of questions (refer to Table 2), called "stem" by the researcher which were intended to prompt students to think critically about the material and to produce further elaboration on what they have learned by answering their own questions. Working alone, students were advised to use the generic question stems as examples to create their own specific questions relevant to the presented material and then write down their answers. Table 2 presents examples of the generic questions that were used by students in the study and their intended cognitive effect.

Table 2.

Generic questions for the self-questioning group

<u>Questions</u>	<u>Cognitive Effect</u>
Explain why...or Explain how...?	Analysis of processes and concepts
What is the main idea of...?	Discovering the central idea of the text
What makes you think this way?	Justifications of current state of the mind
How would you use...to...?	Integrating prior knowledge to new experiences
What is a new example of...?	Generating new ideas by building on prior experience
Does this make sense so far?	Continued linkage of ideas
What is the difference between... and...?	Compare and contrast concepts
What conclusions can you make about...?	Presenting the conclusion of text being read
How does... affect...?	Evaluating relationships between ideas
What are the strengths and weaknesses of...?	Deep analysis and integration of concepts within the text
What is the best... and why?	Using some criteria to evaluate concepts
How is... related to... that we studied earlier?	Prior knowledge activation and integration with new knowledge

In the guided peer questioning condition, students listened to the lecture and then, utilizing the generic question stems, every student independently generated two or three questions relevant to the material. Then, small groups of students engaged in peer questioning and took turns presenting their own questions to each other and answering

each other's questions in a reciprocal manner. The discussion condition encouraged students working in groups to discuss the material presented in the lecture and to exchange ideas related to the content. The last condition, the unguided independent review of material, asked students to review the presented material independently, looking for important relationships, key points, etc. By means of objective and essay tests requiring recall and understanding of the lecture content, each of the strategy conditions were immediately tested after each practice session. The results indicated that students in both guided self-questioning and guided peer questioning significantly improved their lecture comprehension compared to the discussion condition and the independent review condition. The discussion group outperformed the independent review group. Furthermore, students in the guided peer questioning group outperformed students in the guided self-questioning group.

King (1991) conducted another study on ninth grade high-school students using their regular class lectures this time. The same four treatment conditions as in King (1989) were used: guided learner-generated questioning, guided peer questioning, unguided small group discussions, and unguided independent review. Results were identical to King's (1989) experiment; students in the guided self-questioning condition and peer questioning condition showed better recall and understanding of the lecture content than students in the discussion and review conditions. Again, students in the guided peer-questioning group outperformed students in the guided self-questioning group. Chi, Siler, Jeong, Yamauchi, and Hausmann (2001) did a study using human tutors in which students were encouraged to construct their knowledge by suppressing the

human tutors from providing feedback (i.e. answering questions arising during the tutoring session) and encouraged them to self-explain. During tutoring meetings, human tutors asked students questions that would further their thinking through self-explaining about the material, rather than give them the direct answers or asking questions that would raise new issues that were unrelated to the student’s reasoning. Self-explanation was driven by using content free questions that would direct students focus yet not give any content specific information regarding the subject matter. These prompts were obtained from previous research and literature on tutoring. As an example, Table 3 presents 9 samples of the 69 content-free prompts used in the study.

Table 3.

Chi’s content-free prompts

	<b><u>Question (prompt)</u></b>
1	Any thoughts about that sentence?
2	Could you explain the concept of the idea discussed in this sentence?
3	What’s going on here?
4	Could you think of anything else?
5	How?
6	Why?
7	What do you understand from this passage?
8	Anything else you can tell me about it?
9	Why do you suppose that is the case?

Students were given a passage about the human circulatory system and prompted to answer elaborative questions in order to construct their own understanding of the ideas about the passage based on their prior knowledge and experience. This was hypothesized to motivate students to integrate new information with pre-existing intellectual constructs. Students learned as effectively as if they were given feedback. In a previous study, Chi et al. (1994) found that students prompted to give self-explanations of a text on the same circulatory system passage used in Chi et al. (2001), had greater gains from pretest to posttest than a control group asked to read the passage twice. Also, students who explained more, by looking at the amount of elaborations produced by each participant, had better understanding of the material than students who generate less self-explanations.

For the purpose of this study and in accordance with the objective of finding simple yet effective intervention strategies, subjects will be provided with a list of example questions, compiled from the list of questions used by Chi et al. (2001) and King (1989, 1991, 1992b). Students experiencing this strategy will see a list of questions that they can use as a guide to come up with their own questions after reading the curriculum content. The computer-based instructional system, at designated intervals, will instruct the students to ask themselves questions regarding the passage that they just read. Then, they will type in their elaboration in the text editor available in the system. More specific aspects on the interaction and operational aspects between students and the computer instructional system will be discussed in detail in chapter 3.

## **Advance Organizers**

An advance organizer is a road map in a form of a short set of verbal or visual information that is presented prior to learning a larger body of content (Stone, 1983). Ausubel (1961) first used this term to describe the process of linking the upcoming unfamiliar learning material to what is already known to the learner. He defined advance organizers as “appropriately relevant and inclusive introductory materials that are maximally clear and stable. . . introduced in advance of the learning material itself, used to facilitate establishing a meaningful learning set.”

Advance organizers become conceptual "bridges" from the prior knowledge to the information to be learned (Peterson, Glover, & Ronning, 1980). They give the student a "what to look for" which is a frame of reference that provide hooks or anchors to knowledge previously acquired. They may give the student background information and/or assist the student to remember and apply old information. Examples of advance organizers include compare/contrast structures, Venn diagrams, matrices, or just a written queue card (Royer & Cable, 1976). Figure 4 depicts a teacher advance organizer (Taylor & Taylor, 1983).



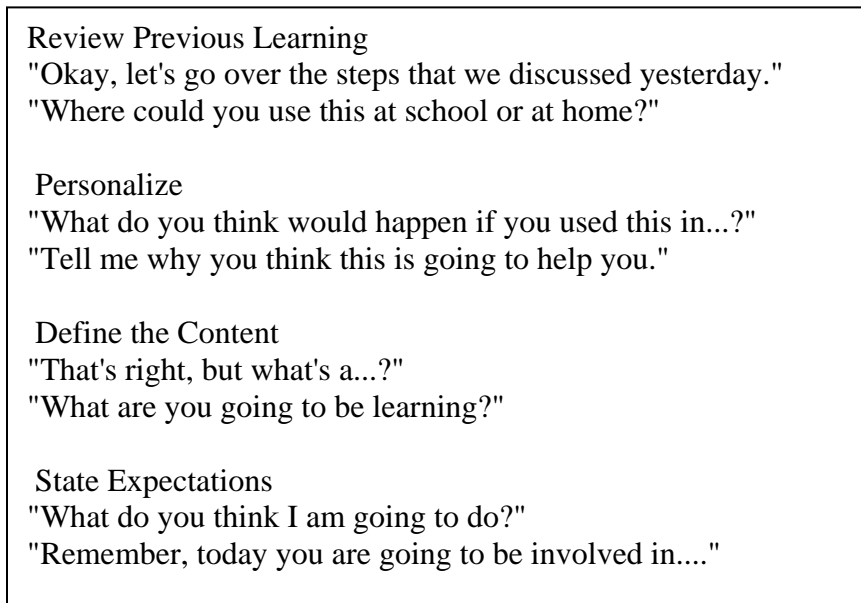


Figure 4. Teacher's Sample Cue Card for Using an Advance Organizer

According to Schwartz et al. (1998) advance organizers could “help mobilize relevant schema and provide means of organizing new materials” thereby it increases learner’s comprehension and recall. Advance organizers are usually given at the beginning of the lesson but may be used as the lesson unfolds to reinforce and direct student thinking. Examples include, but are not limited to, stating clear and interesting objectives and expectations, making generalizations, defining terms, reviewing previous learning, and personalizing the learning (Mayer 1979). Mayer (1979), also defines the characteristics of an advance organizer as “(a) a short set of verbal or visual information, (b) presented prior to learning a larger body of to-be-learned information, (c) containing no specific content from the to-be-learned information, (d) providing a means of

generating the logical relationships among the elements in the to-be-learned information, and (e) influencing the learners' encoding process.''

Many researchers have investigated the effectiveness of applying advance organizers. Much research shows that advance organizers do facilitate learning. For instance, Luiten, Ames, and Ackerson (1980) conducted a meta-analysis of 135 advance organizer studies and concluded that advance organizers have a "facilitative effect" on the learning process. One of the original research studies conducted on advance organizers is a series of four experiments by Ausubel and colleagues (Ausubel, 1960; Ausubel & Fitzgerald, 1961; Ausubel & Fitzgerald, 1962, Ausubel & Youssef, 1963), which indicated the usefulness of advance organizers as an instructional strategy to improve reading comprehension from text. For instance, in Ausubel (1960) 110 undergraduate students were exposed to an unfamiliar expository passage about metallurgical properties of metal. They were assigned to two groups: experimental and control. Subjects in the experimental group read a 500-word advance organizer text, presenting main features of upcoming material, before reading the metallurgical properties of metal passage. The control group read a 500-word historical introduction to steel production, which did not reveal any information about upcoming material, before reading the metallurgical properties of metal passage. In a multiple-choice posttest, the experimental group scored significantly higher than the control group.

Other studies have indicated that advance organizers can help students learn better not only from written material but also from material presented in videotaped format. Herron (1994) investigated the effect of using an advance organizer to teach French

language using video to American college students. The study utilized 38 students in two sections (conditions) for a semester long, beginning level French 102 course. In the advance organizer condition, the teacher provided students with several short sentences written on the board in French, which summarized, in chronological order, major scenes in an upcoming video segment. Students then watched the video in its entirety with no further teacher manipulation of material. In the control condition, students, with no introductory statements by the instructor, watched the video in its entirety without any manipulation of material. A total of 10 comprehension and retention tests were taken by students to cover the material presented in 10 different tapes during the course of the study. The mean score of the advance organizer condition was significantly higher than the mean score for students in the control condition.

Herron, Hanley, & Cole (1995) conducted another study to compare two advance organizers for introducing beginner foreign language students to videos. They compared two advance organizers: one was an aural description of major upcoming scenes in the video accompanied by contextually related pictures; the other contained only the aural description. Their findings suggest that the beginner-level college French students' comprehension and retention of information in a French video series is significantly improved from using the description + pictures advance organizer than from the aural description only advance organizer.

From the above discussion on the structure of advance organizers, it appears that advanced organizers require more cognitive effort on learner's behalf, with respect to the involvement with lesson content, than using other interventions such as

revising the contents. This “more involvement” with the curriculum is expected to force students to generate more connections, improve learners’ schema of the topic, and hopefully improve the learning outcomes. In the next chapter, we will demonstrate how to incorporate advanced organizers into computerized instructional systems in two different fashions. The traditional advanced organizers as discussed in the literature review where we will provide an advance organizer at the start of the learning experience and in a new innovative way by asking students to come up with their own organization of the curriculum.

### **Hypothesizing and Justifying**

Hypothesizing and justifying are considered to constitute more complex, deeper, and suit a higher level of constructive learning (Chi et al., 2001). In order to make a hypothesis and justify the line of thought, an individual needs to describe a new realization, make an effort to solve a problem, and attempt to understand difficult issues. In doing so, the individual needs to integrate much of the new information with established knowledge he or she already has in his/her existing cognitive structures.

In an experiment by Chan, Burits, Scardamalia, and Bereiter (1992), 109 children from a middle class urban school were asked to read from two informative texts, one about germs and the other about dinosaurs. Each text consisted of 12 expository statements. They tested four instructional strategies prior to a thinking aloud session that was common to all groups. The groups where hypothesizing and justifying (named

modeling by the researchers), know, do not know, and a control group.

In the Hypothesizing and justifying group, students were trained to give thinking ideas about text sentences being read. Groups of three to four students were formed and received training for half an hour one week before the testing session. Deep thinking was defined to learners as describing new realization, making an effort to justify a solution to a given problem, or attempting to understand difficult points. Deep thinking was illustrated by examples of “thinking ideas” about the text as opposed to “easy ideas.” First, experimenters provided children with an example of how to give thinking ideas. For instance, in reaction to the statement, “Cats sleep more than any other animal, though scientists don’t know why,” an easy idea could be “My cat likes to sleep on my pillow,” while a thinking idea could be, “I wonder why cats need to sleep that much, maybe there are lazy. Or, maybe it’s the other way around. Maybe they are not lazy. Maybe they use extra energy when they are awake so they get more tired than most animals.” After that, children were given two ideas and asked to assess which one was an easy idea and which one was a thinking idea. The final step in training children to hypothesize and justify involved children generating their own ideas and assisted each other to evaluate these attempts.

The know group, was asked to tell what they already knew or understood about the topic they were assigned. The do not know group, was asked at the beginning of the learning session to talk about what they did not know about the topic they were assigned to. The training sessions for these two treatments lasted about 15 minutes in which the experimenters met with children individually and asked each child to “say out loud

everything that comes out to your mind as you try to learn from this statement.” Initially, the experimenter provided an example and modeled thinking aloud. Then, the child was asked to think aloud to a statement and the experimenter provided feedback. Finally, the child was asked to practice thinking aloud to two more statements. The control group students did not receive any special treatment.

The testing of the four treatments started with the thinking aloud session. The experimenter read the 12 expository statements to each child, stopping after each statement, and asks him/her to think aloud. The procedure was repeated if the experimenter thought the child had not understand or if the child asked to repeat. After the thinking aloud session, experimenters met with students, individually, and the sessions were recorded and later transcribed. The interviewer asked learners four questions aimed at assessing recall and fostering knowledge construction:

1. The youngsters were asked to recall everything he/she remembered about the text.
2. The youngsters were asked to summarize the main idea of the text.
3. The youngsters were asked to tell everything new he/she learned about the topic.
4. The youngsters were asked to tell what else he/she would like to know about the topic.

One notable outcome of the study was the development of a scale of constructive activities. They analyzed the elaborations provided by learners and developed a scale of five levels of constructive activities:

1. Pre-factual confabulation (telling isolated words or fragmented phrases which indicates no understanding of the text).
2. Knowledge retelling.
3. Assimilation (telling explicit evidence of comprehension of the text).
4. Problem solving.
5. Extrapolation (telling an extension of knowledge beyond what was given in the text).

The post-test results suggested that age differences play a role in the use of the constructive activities. Children in grade 1 tended to focus on surface features. Grade 3 children appeared to use the assimilation learning more frequently and hence showed simple text comprehension. Grade 6 children made use of both the simple text comprehension and the problem solving activities aimed at constructing deep and meaningful understanding. In addition, there were differences in favor of the hypothesizing and justifying group with respect to learning comprehension.

### **Criticizing, Reflecting, and Predicting**

Reflecting, criticizing, and predicting are integrative instructional interventions that are thought to construct deep understanding. In reflecting and criticizing, learners are asked to transfer expressions into their own words, which will give the tutor an opportunity to monitor the learners' learning. In addition, when asking learners to clarify, the tutor will engage them in critical evaluation of the content being learned. Criticizing strategy involves generating differing opinions critical of what is being learned. When criticizing, the learner tries to understand exactly what is going on and attempt to provide valuable information to their tutor. For a discussion of a specific technique, called co-investigation, for encouraging students to reflect and criticize see Scardamalia and Bereiter (1983).

Predicting, on the other hand, requires the learner to make inferences about upcoming material from what he or she has already learned (Palincsar & Brown, 1984). Predicting may come in the form of questions that concern with material that is not yet covered. Palincsar & Brown (1984) conducted a study of four elaborative strategies summarizing, questioning, reflecting, and predicting. They found that using reflecting and predicting led to a significant improvement in the learning process as measured by an improvement in standardized comprehension scores.



## **Elaborative Strategies and the Levels of Processing Approach**

The levels of processing approach, also called the depth of processing approach, proposes that learners can analyze information at a number of different levels ( Craik and Lockhart, 1972). In particular, learners tend to analyze stimuli in either a shallow or a deep level. The shallow levels, or surface level learning, entail analysis in terms of physical or sensory characteristics, such as size or color. In shallow level learning, students tend to concentrate on memorizing declarative knowledge. The deep levels entail analysis in terms of meaning, such as related associations with pre existing knowledge or experiences. This kind of learning requires student to analyze procedural knowledge. They suggest that deeply processed information will lead to a more permanent memory trace and eventually result in an enduring retention as compared to shallow kinds of processing. The levels of processing approach has been one of the most influential theories in the area of human memory. It has been referenced more than 700 times in human memory research (Roediger, 1980).

Craik and Lockhart also affirmed that rehearsal strategies (learning strategies) would lead learners to process information at deeper levels, which will result in a lasting impact on the learning outcome. Two kinds of rehearsal strategies were proposed. Maintenance rehearsal merely repeats the kind of analysis that has already been carried out. In contrast, elaborative rehearsal, like the ones discussed earlier in this chapter, involves a deeper, more meaningful analysis of the new information. For example, using maintenance rehearsal to learn the new concept “steam engine”, one could simply repeat the sound of these words. On the other hand, one could use elaborative rehearsal by

developing an analogy of the steam engine or by relating the concept “steam engine” to past knowledge about steam-powered machines.

In addition to emphasizing the importance of elaborative strategies on creating highly memorable learning outcomes, the depth of processing approach can be used to classify elaborative strategies that have been identified previously. We believe that each elaborative strategy will motivate learners to process information (stimuli) at a particular depth. For instance, generating a hypothesis about a text would require a deeper, and more demanding, level of processing than using the revising strategy to learn from the same text. According to Anderson and Reder (1979) the “variation in memory with depth of processing is a result of the number of elaborations subjects produce while studying the material.” We propose that different elaborative strategy will prompt learners to produce different number of elaborations and hence a different memory trace.

Table 4 lists the elaborative strategies according to the level of processing they demand on learner’s behalf. It should be noted that this ranking presuppose further empirical evidence and that is beyond the purpose of this research.

Table 4.

Elaborative Strategies Ranked in Ascending Order

Revising
Predicting
Generative Summarizing
Analogies
Self-explaining
Justifying
Reflecting
Advance Organizers
Criticizing
Hypothesizing

## **CHAPTER 3: THE COMPUTER BASED INSTRUCTIONAL SYSTEM**

The computer-based information system utilized in this work is based on the curriculum developed by Williams & Lopez (in press) that teaches trainees the bus system of the US Army Abrams M1A2 tank. The curriculum is presented next followed by a detailed discussion on how to incorporate the knowledge construction interventions into the computer-based instructional system.

### **The Army Abrams M1A2 SEP Tank**

The M1A2 Abrams Main Battle SEP (System Enhancement Program) Tank is the namesake of the late General Creighton W. Abrams, former Army Chief of Staff and commander of the 37th Armored Battalion. It is the backbone of the armored forces of the United States military, and several of US allies as well. The purpose of this vehicle is “to provide mobile firepower for armored formations of sufficient capability to successfully close with and destroy any opposing armored fighting vehicle in the world, while providing protection for its crew in any conceivable combat environment. It is capable of engaging the enemy in any weather, day or night on the multi-dimensional, non-linear battlefield using its firepower, maneuvers, and shock effect. The Abrams Tank System synchronizes its high tempo, distributed maneuver via its digitized situational

awareness and the fusion of onboard and remote battlefield sensors” (Federation of American Scientists, n.d.) .The Abrams tank is the most sophisticated and advanced tank in the world. Since its initial fielding in the mid 1980’s, the system has gone through several enhancements and modifications. The M1A2 tank, best known for its success during the Persian Gulf War, has changed significantly in the last decade. The addition of a commander’s independent thermal viewer, self diagnostics and fault detection for turret and some hull components, an on-board global positioning system, and an embedded command, control and communications platform, have increased its lethality, and the survivability of the Abrams on the battlefield. These enhancements are possible because of the increased sophistication of the on-board electronics, and software that controls almost every function of the tank. To control and monitor all of these functions, the Abrams incorporated the Military Standard (MIL-STD) 1553b data bus into its architecture.

### **The Data Bus**

According to Williams and Lopez (in press), the MIL-STD 1553b is a military standard that defines a dual-redundant communications network. This communications network, also referred to as a data bus, was initially developed for use in avionics systems in the late 1960’s, but is today also used in submarines, tanks, and missiles. It is a highly reliable bus, both because of its low error rate and its dual-redundant capability. The MIL-STD 1553b data bus used for the M1A2 SEP consists of a bus controller, a bus

monitor, and six remote terminals. These components are connected to cables and couplers that are located on each side of the tank. Because of this configuration, one side of the 1553b can be damaged, and the other side has the capability to perform the entire task. In addition to the dual redundant nature of the cables and couplers, each component that resides on the 1553b has a backup that provides full or partial functionality. On the M1A2 SEP the tank's fire control, command control and communications, navigation and diagnostics functions rely on an operational data bus.

### **The Curriculum**

The curriculum developed by Williams and Lopez (in press) described the functions and mechanisms associated with the 1553b data bus system. The 1553b data bus is the data distribution network that is responsible for the control and monitoring of all the functions and applications of the M1A2 SEP tank. The curriculum was developed by extracting mental model of the 1553b data bus tank subject matter experts (SME) of the US army, through a series of interviews, of how the 1553b data bus operates. Williams and Lopez employed a method developed by Miyake (1986) to extract mental models from individuals, interacting with each other, and conversing on understanding of how a simple physical device works. After decomposing the expert view of the bus system into a function mechanism hierarchy, the “resulting organization of knowledge making up the mental model of the expert was used to generate instructional curriculum” (see Appendix A).

The structured curriculum was then tested on an experimental group of students against a control group of students using a combination of the “then” current curriculum and technical manuals to determine how efficiently the students could acquire knowledge about how a device works and how accurately they can reason and solve problems concerning device operations. Students took a pretest to provide a baseline for subject understanding before starting the experiment trials. The experiment involved three trials, in each trial; students had to read the presentation relevant to their group and upon completion of reading take a posttest to measure performance.

The results of the experiment clearly showed using the structured curriculum had a profound impact on learning. Students using the experimental curriculum outperformed students in the control group in answering the two types of questions presented in the posttest; verbatim questions such as explaining the functions of a specified device and inference questions that require cognitive manipulation of the material to arrive at the correct answer. Moreover, students in the experimental group learned the material more efficiently as indicated by the mean time required to learn the system. The control group took almost 65 minutes to achieve approximately the same score that the experimental group achieved in just 28 minutes (i.e. the experimental group acquired its mental model in the equivalent of accuracy as the control group does in approximately 1/3 the time).

We were fortunate in this research for having the opportunity to use this highly structured curriculum, this would allow us to concentrate on the implications of adding the knowledge construction and their effect on learning without worrying about the impact of the instructional material itself.

## **Incorporating the Interventions**

An attractive feature of the instructional interventions is the ease of implementation to any curriculum with little or no additional cost in terms of time and programming. We have found good evidence in favor of the summarizing, self-questioning, and the advance organizers strategies. In addition to their effectiveness in enhancing the learning outcomes, they demand different level of elaboration on student's behalf. The three selected strategies represent low, medium, and high levels of elaborative activity. Table 5 shows where the three selected strategies stand in the ranking of elaborative strategies according to the level of processing and elaboration demanded on learner's behalf. We wanted to see that engaging students with different elaborative strategies, and hence cognitive activity, would result in different learning outcomes. One of the hypotheses of this research is that the more students are involved with the curriculum the more the connections are generated and ultimately a better learning experience. Furthermore, each strategy will be implemented in a low and high generative fashion to assess the utility of the generation within each strategy. The implementation aspects will be discussed in detail in the coming.



Table 5.

The Selected Elaborative Strategies

Revising
Predicting
<b><i>Generative Summarizing</i></b>
Analogies
<b><i>Self-Questioning</i></b>
Justifying
Reflecting
<b><i>Advance Organizers</i></b>
Criticizing
Hypothesizing

To facilitate comparison of the different prompts, the following measures were considered when integrating the prompts into the curriculum:

1. Prompts were placed at the same location in the curriculum for the summarizing and the questioning interventions.
2. The same keywords and concepts were used for all interventions.

### **Generative Summarizing**

Generative summarizing used in this study will compare two types of summary writing approaches: sentence completion and sentence generation. The collection of these sentences presents a summary of the important concepts and elements of the curriculum.

In the sentence completion condition that is designed to generate low level of elaborations, learners will be asked to complete sentences throughout the curriculum.

Figure 5 demonstrates a system message instructing learners to complete a sentence.

Refer to Appendix B for the complete curriculum with the sentence completion prompts.

**The (TMPU) and the (HMPU) are connected  
by means of (cables) and (couplers) through  
the (slip ring).**

Figure 5. A Message Requesting Students to Complete a Sentence

The sentence generation group were asked to generate their own sentences using provided keywords and concepts from the curriculum. Figure 6 demonstrates a system message instructing learners to generate their own sentences using the provided key words. Refer to Appendix C for the complete curriculum with the sentence generation prompts.

**Generate a sentence using: (TMPU), (HMPU),  
(cables), (couplers), and (slip ring).**

Figure 6. A Message Asking Students to Generate a Sentence

## Questioning

In the questioning intervention, two variations of the questioning intervention were used. In the low generative questioning intervention, the information system provided the questions and demanded answers from the participants. In the high generative questioning intervention, participants were required to ask their own questions and then answer their own questions.

In the system provided questions, learners will see a screen like in Figure 7 asking them a question and require an answer. Refer to Appendix D for the complete curriculum with the provided questioning intervention.



**How are the TMPU and HMPU connected?**

Figure 7. A Prompt Asking Students to Answer System Provided Question

Participants in the high generative questioning intervention will see a list of questions that they could use as an aid to generate their own questions and produce further elaboration during their interaction with the curriculum. Examples of questions were provided at the beginning of the curriculum (see Figure 8).

Please read the material at your own pace. During your reading, you will be prompted to pose questions about the material and answer them. Consider the following question as a guide to generate your own questions:

Any thoughts about that sentence?  
Could you explain the concept of the idea discussed in this sentence?  
What's going on here?  
How?  
Why?  
What do I understand from this passage?  
Anything else you can tell me about it?  
What is the main idea of...?  
What makes you think this way?  
How would you use...to...?  
What is a new example of...?  
Does this make sense so far?  
What is the difference between... and...?  
What conclusions can you make about...?  
How does... affect...?  
What are the strength and weaknesses of...?  
What is the best... and why?  
How is... related to... that we studied earlier?

Figure 8. Stem of Generic Questions

At various points in the learning experience, the instructional system will prompt subjects to pose question and provide appropriate answers to their questions in the space provided by the system, see Figure 9 for an example prompt. Refer to Appendix E for the complete curriculum with the generated questioning intervention.

**Ask a question about how components are connected and answer it.**

Figure 9. A Prompt Soliciting Questions and Answers

## **Advance Organizers**

Two types of advance organizers were used in this study. The first one is the regular advanced organizer that were designed to give students anchors and links from their prior knowledge to the information presented and to direct their attention to the important concepts in the curriculum. This type of advance organizers was presented at the beginning of the learning experience. The second type is an innovative way of using advance organizers, we asked students to come up with their own organization after reading the curriculum.

Figure 10 presents the advance organizer used in this study, which is a short introduction of verbal information intended to activate any relevant schema (though it is very unlikely to prior knowledge about the bus system) and help organize new materials within student's existing knowledge structures. Refer to Appendix F for the complete curriculum with the provided advance organizer.

### **Organization of the content**

The curriculum you are about to read describes the data bus of the army Abrams tank.

The data bus communicates all data messages to control and monitor the functions and application of the tank. Below is a highlight of the major components and features of the data bus:

\* **Turret Mission Processing Unit (TMPU):** the bus controller, sends and controls all kinds of messages between different components, manages talking between components, initiate fault diagnostic, and calculates ballistic solutions.

\* **Hull Mission Processing Unit (HMPU):** If the bus controller fails, the bus monitor will assume all functions of the bus controller except the use of the GPS.

\* **A and B Buses:** Connects the bus controller with remote terminals through redundant **Cables and Couplers** through the **Slip Ring**.

\* **Remote Terminals:** Each performs a specific function; operate in response to bus controller commands.

### **Interesting features that you will read about**

- The bus will still function even if it is considerably damaged. This feature is referred to as dual redundancy:
  - How the cables are routed along different paths throughout the tank and why?
  - What component would takeover in case the bus controller is not functioning?
- Couplers and their ability to ensure that failure of one component will not result in main bus failure.
- The data bus fault diagnostic systems.
- The availability of many displays to control, monitor, and check tank functions by the crew and service mechanics.

Figure 10. The Advance Organizer



Participants in the generated advance organizer group received an introductory slide informing them that will have to provide their own organization of the curriculum after they completed reading the material (see Figure 11).

After you completed your reading, you will be asked to describe how the curriculum is organized. Your organization should address the important concepts of the curriculum. You will be asked to present your organization in a nested bullets format, like the example below:

**University Park Colleges and Departments**

1. Agricultural Sciences
  - A. Agricultural and Biological Engineering
  - B. Agricultural Economics
  - C. ...
2. Arts and Architecture
  - A. Architecture and Landscape Architecture
    - i. Department of Architecture
    - ii. Department of Landscape Architecture
    - iii. ...
  - B. Art History
  - C. ...
3. ...

Figure 11. Prompt Directing Attention to the Advance Organizer

On the last slide of the curriculum, participants were presented with a list of all

the functions and mechanisms of the data bus and were asked to generate their own organization of the curriculum (see Figure 12). Refer to Appendix G for the complete curriculum with the generated advance organizer.

Now you have finished reading, we wanted you to write your thought about the organization of the curriculum. Imagine that this organization would be given prior to learning for other students, which will assist them in having an overview of the bus system, and direct their learning toward upcoming key elements in the curriculum. The organization should include the following components and functions (listed randomly):

- Gunners Control and Display Panel (GCDP)
- Isolate components preventing damage to bus
- Connects remote terminals via A and B bus
- Couplers
- Monitor Engine Systems
- Slip Ring
- 1553B data bus
- Carry Information
- Dual Redundant
- A bus and B bus
- Self Test (ST)
- Connects the controller, monitor, and remote terminals
- Commanders Display Unit (CDU)
- Remote Terminals
- Backup Controller
- Bus Controller (TMPU)
- Drivers Integrated Display (DID)
- Bus Monitor (HMPU)
- Connects remote terminals via A and B bus
- Ballistic Solutions
- Priorities for Communication
- Digital Electronics Control Unit (DECU)
- Fault Isolation Test (FIT)
- Converts Analog to Digital Signals
- Cables
- Communicates data
- Built in Test (BIT)
- System Diagnostics

Figure 12. A Prompt Asking to Generate an Advance Organizer

## CHAPTER 4: METHODOLOGY

### Participants

The participants were undergraduate students (59 males and 25 females, mean age = 21.7) from the College of Engineering and Computer Science (CECS) at the University of Central Florida. Participants were recruited from the general CECS subject pool at the university (see Table 6 for descriptive statistics).

Table 6.

Participants Descriptive Statistics

Gender	Participants	Mean Age
Female	25	21.9
Male	59	21.6
Total	84	21.7

Participants were randomly assigned to the treatments to ensure that each participant had an equal chance of being assigned to any one of the control or the six experimental groups. Participation in the experiment was open to all students, regardless of age, race, gender, or nation of origin. A demographic form was used to screen out

participants with previous mechanical training ensure that only data from naive participants were used in the analysis of the results. Participants who indicated any prior mechanical training were excluded. Treatment of these participants was in accordance with the ethical standards of the APA (see Appendix H for the screening form and the informed consent). All participants received \$20 and extra course credit for their participation.

### **Design**

This study employed several (2 \* 1) repeated measure designs to determine the differences in learning outcomes effected by employing the knowledge construction intervention. The intervention was the first factor between experimental groups. The interventions selected were summarizing, questioning, and advance organizer. As explained before, the treatments were designed to represent low, medium, and high levels of knowledge construction activity that were selected among the different interventions reviewed in this study. The second between groups factor was the level of generation used to prompt participants to elaborate on the materials. The level of generation was designed to solicit two degrees of generative activities, either high degree of elaborative activities or low degree of elaborative activities. The combination of the intervention and the level of generation yielded six different treatment combinations. These treatments were summary completion, summary generation, provided questioning, generated questioning, provided advance organizer, and generated advance organizer. These two

variables were designed to evaluate the overall effectiveness of the knowledge construction interventions. The treatments are shown diagrammatically in Figure 13.

<u>Intervention</u>	<u>Level of Generation</u>	<u>Trial</u>	<u>Treatment</u>
Summary	Completion	T1---T2---T3-----T4 (retention)	(2)
	Generation	T1---T2---T3-----T4 (retention)	(3)
Questions	Provided	T1---T2---T3-----T4 (retention)	(4)
	Generated	T1---T2---T3-----T4 (retention)	(5)
Advance	Provided	T1---T2---T3-----T4 (retention)	(6)
	Generated	T1---T2---T3-----T4 (retention)	(7)
<hr/>			
Control		T1---T2---T3-----T4 (retention)	(1)

Figure 13. The Treatments

The Within-subjects variable was the trials. Subjects were required to read the curriculum across three trials and upon completion of each trial, to take a test. Subjects were also required to take a retention test a week later.

Performance measures used to evaluate study assumptions were test scores, learning gains, study time, and elaboration time. The test consisted of 30 questions that covered key concepts of the functions and mechanisms of the 1553b data bus system. (see Appendix I for the test and answer key). The learning gain was defined as the difference between the score on the test before the trial and the score on the same test after the trial was completed. Study time was a measure of how long it took a subject to study the curriculum presented during the trial. Elaboration time was a measure of how long it took a subject to elaborate in response to the prompts.

### **Materials**

To assess the manner in which the knowledge construction interventions impact the learning outcomes from computerized information systems, the present study utilized the curriculum that describes the functions and mechanisms associated with the 1553b data bus system of the Abrams tank. The tutorials presented to subjects in this study contain the highly structured curriculum used in the previous study (see Williams and Lopez, in press). An online (webct) computer-based instructional system was developed for this research. The computer-based system provided test participants with instructions on how to complete the reading material that described the functions and mechanisms

associated with the 1553b data bus system of the M1A2 SEP tank. The instructions informed participants to read the material at their own pace. Moreover, the instructions explained what kind of activity is used, where to write the elaborations, and how to save their work (see Figure 14).

The screenshot shows a web browser window titled "msn WebCT Quiz - MSN Explorer". The main content area displays instructions for "Group C":

**Group C:**  
Please read the material at your own pace. During your reading, you will be asked to write sentences using key words from the curriculum intended to further your understanding of the material. When you have finished responding to a prompt click "Save Answer", then "Next Question".

Do not click "Finish" until all questions have been read. You will be asked to take a test when you have read all content.

Below the instructions, there is a section for "Question 1" (1 point) with the prompt "Please read the following slide." The slide content includes:

**M1A2 Tank Overview**  
Objective: Familiarization with the M1A2 Tank

The M1A2 SEP combat tank uses high speed, maneuverability, and a variety of weapons to accomplish its mission. The tank provides protection from enemy weapons. It has a crew of four individuals. The driver is located in the hull the Gunner, Commander and Loader are Located in the Turret. This training will focus on the 1553B it is the data communications component of the M1A1SEP

Below the text is a diagram of an M1A2 tank with labels for the crew positions: COMMANDER, GUNNER, DRIVER, and LOADER. The DRIVER is located in the hull, while the COMMANDER, GUNNER, and LOADER are located in the turret.

At the bottom of the question, there is a radio button option:  a. Yes, I have read the above slide. A "Save answer" button is located below the option.

The right sidebar of the interface shows a "Time Remaining" section with a timer at 359:47 (min:sec) and a "Question Status" section with a grid of 43 questions. The status for each question is indicated by a yellow circle (Unanswered), a green checkmark (Answered), or a red X (Answer not saved).

Figure 14. System Provided Instructions



The system also was used to capture test subjects' elaborations using the built-in features of the webct system at the University of Central Florida (see Figure 15).

The screenshot shows a webCT quiz interface in an MSN Explorer browser window. The main content area displays a slide titled "1553 Bus Mechanism" with a text description and a diagram. The text explains that the 1553b data bus consists of a bus controller (Turret Mission Processor Unit) that transmits and receives messages across cables, through the slip ring and couplers. It is dual redundant with both an A bus and a B bus, serving both turret functions and some hull functions. The diagram illustrates the A bus and B bus systems, showing the Turret Mission Processing Unit (TMPU) connected to various components via cables and couplers, and a Slip Ring connecting the two bus systems. A legend identifies couplers as blue squares and cables as lines. Below the slide, there is a question asking if the user has read the slide, followed by a question prompt for a question about the 1553B data bus mechanism and an answer input field. The interface also includes a "Time Remaining" section showing 345 minutes and 54 seconds, and a "Question Status" table with 45 questions.

**1553 Bus Mechanism**

Mechanism: The 1553b data bus consists of a bus controller (also known as the Turret Mission Processor Unit) that *transmits* and *receives messages* across cables, through the slip ring and couplers. The controller communicates to a monitor and other remote terminals on this bus. This 1553b data bus is *dual redundant* with both an A bus and a B bus. It serves both turret functions and some hull functions.

**A and B Bus**

Function: The A and the B buses insure dual redundancy in the system. They distribute messages to all of Remote Terminals and the Bus Monitor/Hull Mission Processing Unit (HMPU) from and to the Turret Mission Processing Unit (TMPU). If any bus is damaged the other bus, either the A or B bus which is not damaged, can

Figure 15. The Computer System Soliciting and Capturing Elaborations

Seven versions, one for the control and six for the experimental groups, of this interactive instructional computer system were developed for this research.

## **Procedure**

The experiment started with a pilot study that ran between July 3<sup>rd</sup> and July 14<sup>th</sup>, 2006, to ensure that test subjects could interact with the computer instructional system with ease and that the system is capable of collecting desired performance measures. Following the pilot study, actual data collection was conducted during the three-month period of September to November 2006.

Upon arrival to the experimental facility, participants were randomly assigned to one of the seven experimental groups. The experimental sessions consisted of three phases. The first phase involved subject screening, orientation, and pretest. The purpose of this phase was to gather information on the subjects and provide them with an overview of the experiment. The personal data collected from the individuals was limited to age and gender, along with questions about their background relative to their maintenance experience. Subjects with prior mechanical experience were excluded from the experiment. The informed consent form provided the subjects with information about the purpose of the experiment, and the time required for completing the experiment (see Appendix H). A pretest was given to all subjects to assess the homogeneity of participants entering the experiment. The pretest utilized the same test presented following each trial and was intended to assure that all seven experimental conditions were equal (see Appendix I for the test and the answer key). When subjects were given the test, they were told to answer all questions. If they did not know an answer, they were told to write "I don't know."

Upon completion of the pretest, subjects were asked to log on to the computer

presentation associated with their treatment to start phase two of the experiment. The second phase of the study involved experimental trials, each lasting approximately 30 to 65 minutes. The instructions for the subjects were the same for each trial and each test. When the subjects were given the test, they were told to answer all questions, and if they did not know an answer, they were told to write “don’t know.” Subjects studied the presentation at their own pace and had an unlimited amount of time for studying the material on the computer. When they finished reading, the computer system instructed them to press “finish” to end the session and they were provided with a paper and pencil posttest. Upon completion of the posttest, trial 1 was terminated, and subjects again were asked to re-open the computer instructional system for the appropriate presentation. Upon completion of the posttest in trial 3, subjects were told they were done with phase two of the experiment and informed to return a week later to take the retention test. During the test, subjects did not have access to the training material. The test (see Appendix I) is the same test for each trial. Study time was recorded automatically by the computer system for each of the three trials.

Phase three of the experiment was intended to assess retention regarding each treatment combination and was performed exactly one week from their participation in phase two. Subjects had no access to the curriculum and were asked to take only the test. After completing phase three, subjects were told that they have completed the experiment and were given \$20 in appreciation for the time and effort they exerted on the study.

## **CHAPTER 5: RESULTS**

### **Overview**

The overall results of the experiment supported the hypothesis that prompting learners to construct and generate their own elaborations can lead to improved learning as detailed by their performance on the test, beyond the mere presentation of the materials. The results of the experiment indicated that the experimental groups achieved better test scores, as demonstrated by greater gains between trials than the control group. An alpha level of 0.05 was used for all statistical tests.

### **Analysis of Pre-Test Scores**

A one-way ANOVA was performed to establish the equality of the control and the six experimental groups. The results of the F-test indicates that the mean score at the pre-test for all groups was not significantly different,  $F(6, 77) = 1.00, p = 0.432$ . The majority of subjects did not answer any questions in the pre-test. This was expected due to the unfamiliarity with the curriculum and consequently, the test.

**Effect of the Interventions & Level of Generation**

To evaluate the effect of interventions, level of generation, and trials on performance at test score, a three-way mixed effects ANOVA (3\*2\*3) with a two between subject factors (interventions and level of generation) and one within subjects factor (trials) was conducted. The dependent measure was the test score (see Table 7).

Table 7.

ANOVA Results on Test Score for Trial 1-3

Source	df	MS	F	Sig.
Between subjects				
Intervention	2	163.569	3.301	0.043
Level of Generation	1	39.398	0.795	0.376
Intervention * Level of Generation	2	166.673	3.363	0.041
Error	66	49.556		
Within subjects				
Trials	2	553.771	126.819	0.000
Trials * Intervention	4	6.771	1.551	0.191
Trials * Level of Generation	2	2.558	0.586	0.558
Trials * Int. * Level of Generation	4	4.819	1.104	0.358
Error (Trials)	132	4.367		

The ANOVA resulted in a main effect for the intervention,  $F(2, 66) = 3.301$ ,  $p = 0.043$ , see Figure 16 for a graphical display for the mean scores for the different interventions.

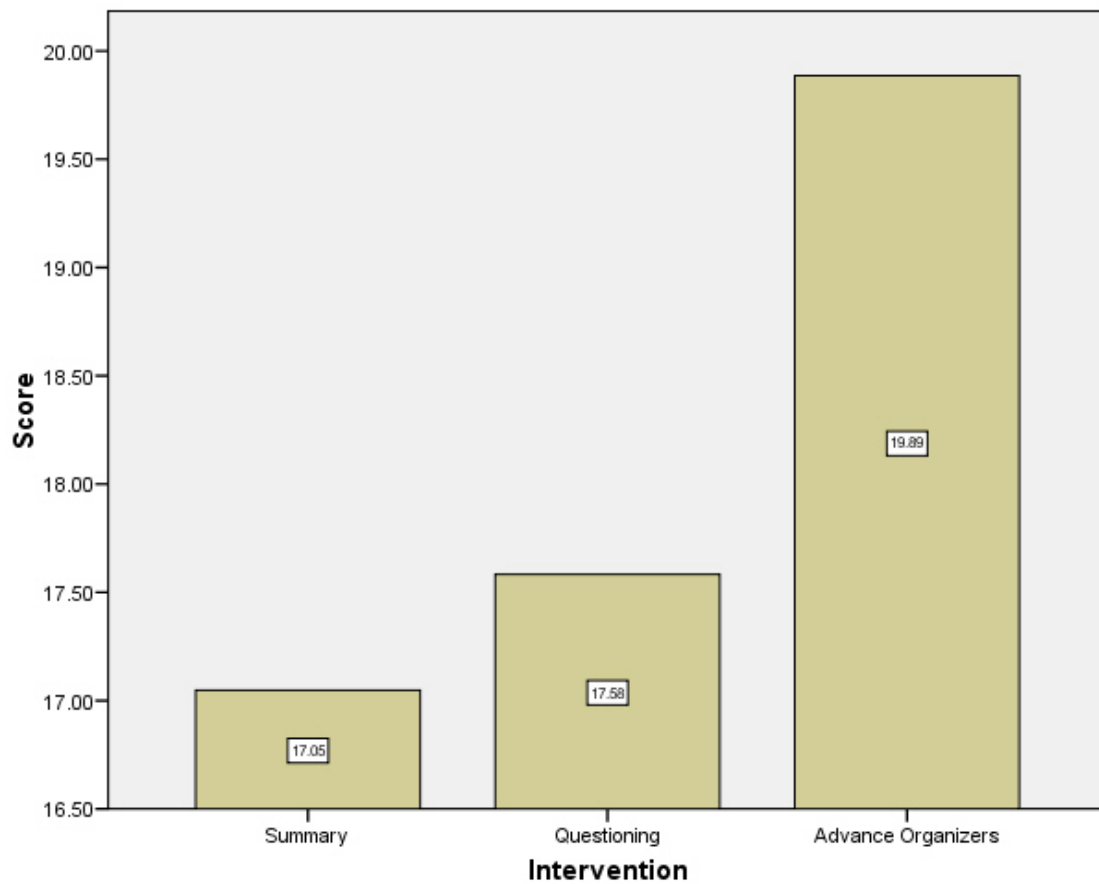


Figure 16. Mean Score for the Interventions across all Trials

Further post hoc analysis of test scores using the Tukey Honestly Significant Difference test (Tukey HSD) revealed that the advance organizer intervention outperformed the summary intervention on mean test score across the three trials (see Table 8).

Table 8.

Means and Pairwise Comparisons of the Interventions

Intervention (Mean Test Score)	Summary 17.049	Questioning 17.583	Advance Org. 19.885
Summary 17.049	-----	0.892	0.048*
Questioning 17.583		-----	0.130
Advance Org. 19.885			-----

\*Significant at 0.05 using Tukey HSD

As expected, there was a significant main effect for the trials,  $F(2, 198) = 126.819, p = 0.000$ , (see Figure 17).

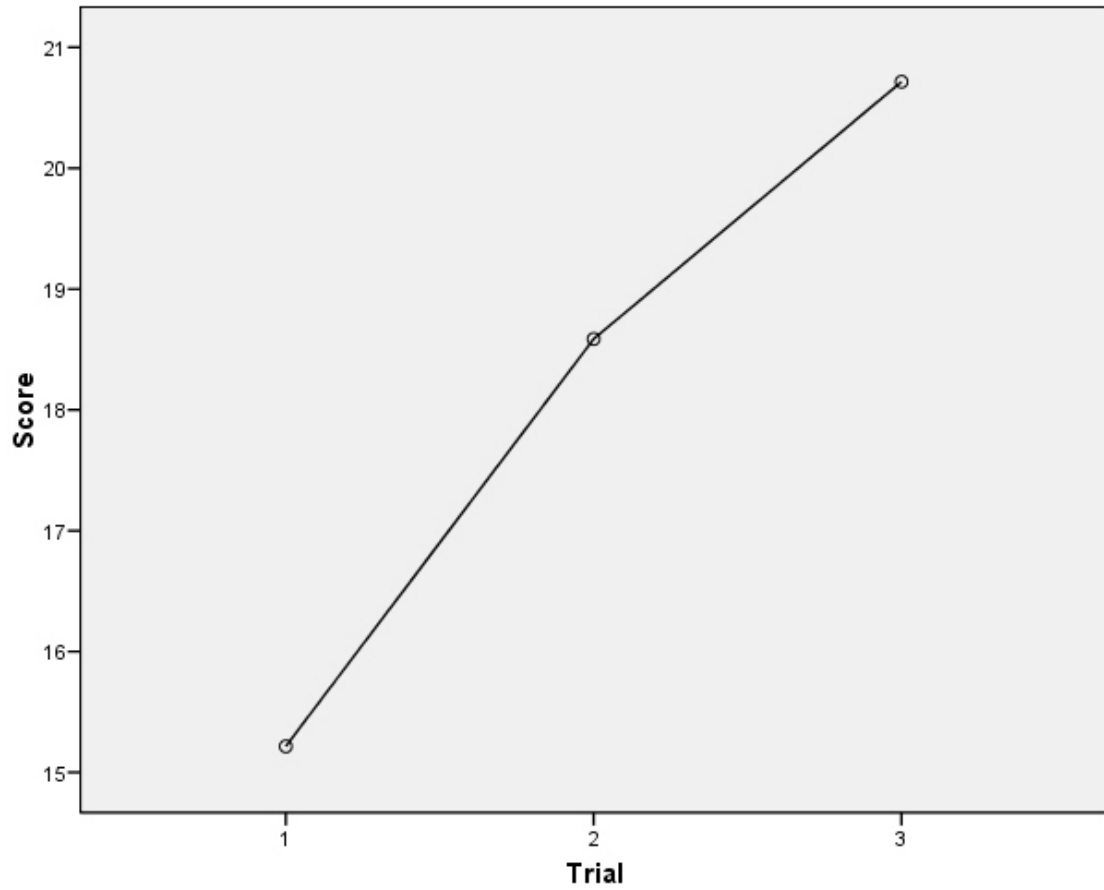


Figure 17. Plot of Means of Score in the Trials across all Interventions



The intervention \* level of generation interaction was significant,  $F(2, 66) = 3.363, p = 0.041$ ). It was interesting to observe that the high generative interventions, in the case of the advance organizers and questioning, did not turn out better learning than the low generative interventions. In fact, the low generative provided advance organizers secured the best score in the three trials (see Figure 18).

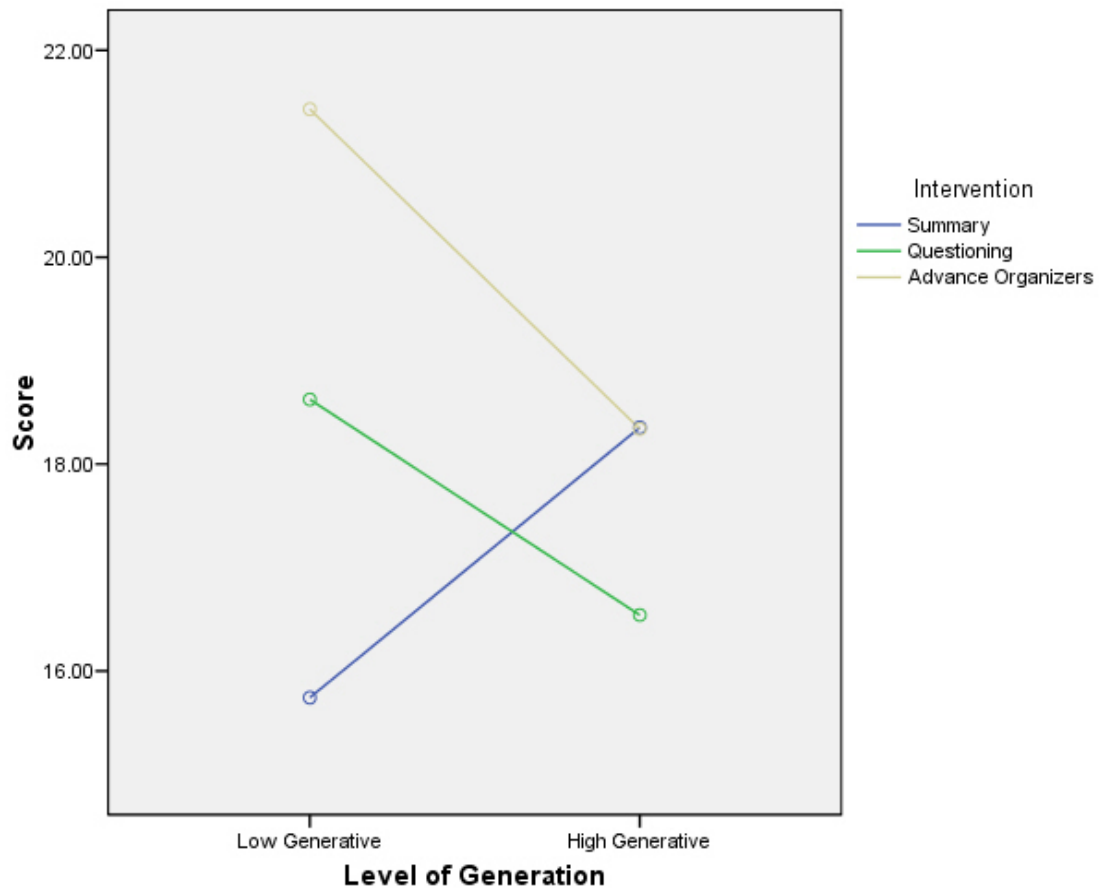


Figure 18. Interaction of Intervention & Level of Generation on Score

Figure 19 presents a graphical display of the performance of the participants on each test pertaining to each intervention during the three trials.

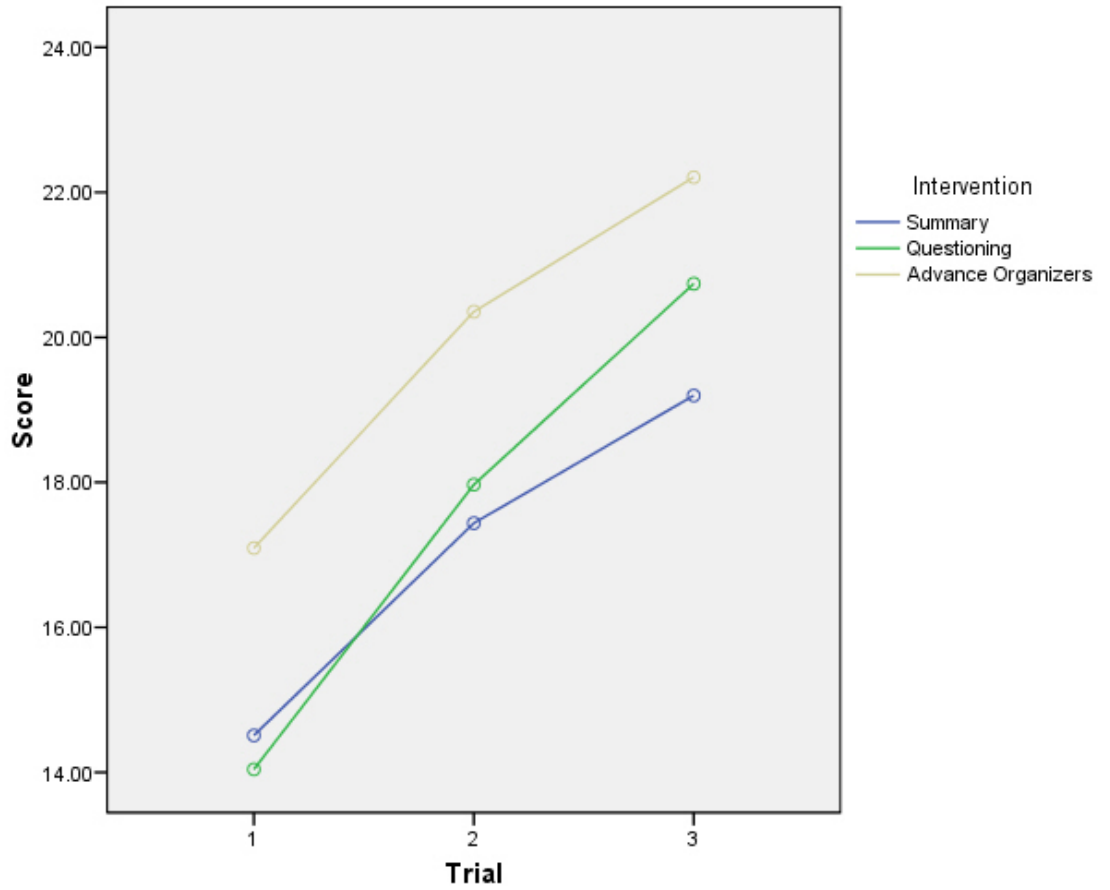


Figure 19. Plot of Means of Score in Trial 1-3 for the Interventions

### **Control Group and the Interventions**

As the level of generation factor was not significant, an analysis was conducted on test performance differences between the three interventions and the control group. A two-way mixed effects ANOVA (4\*3), with intervention (control; experimental) as between subjects factor and trials as within subjects factor was performed. The performance measure was the mean test scores for each trial. The ANOVA results are shown in Table 9.

Table 9.

ANOVA Results for the Interventions and the Control Group

Source	df	MS	F	Sig.
Between subjects				
Intervention	3	659.939	12.782	0.000
Error	80	51.632		
Within subjects				
Trials	2	674.918	152.837	0.000
Trials * Intervention	6	7.877	1.784	0.106
Error (Trial)	160	4.416		

The ANOVA indicated a main effect for the intervention,  $F(3, 80) = 12.782, p = 0.000$ . See Figure 20 for a graphical display for the mean score for the interventions and the control group across all trials.

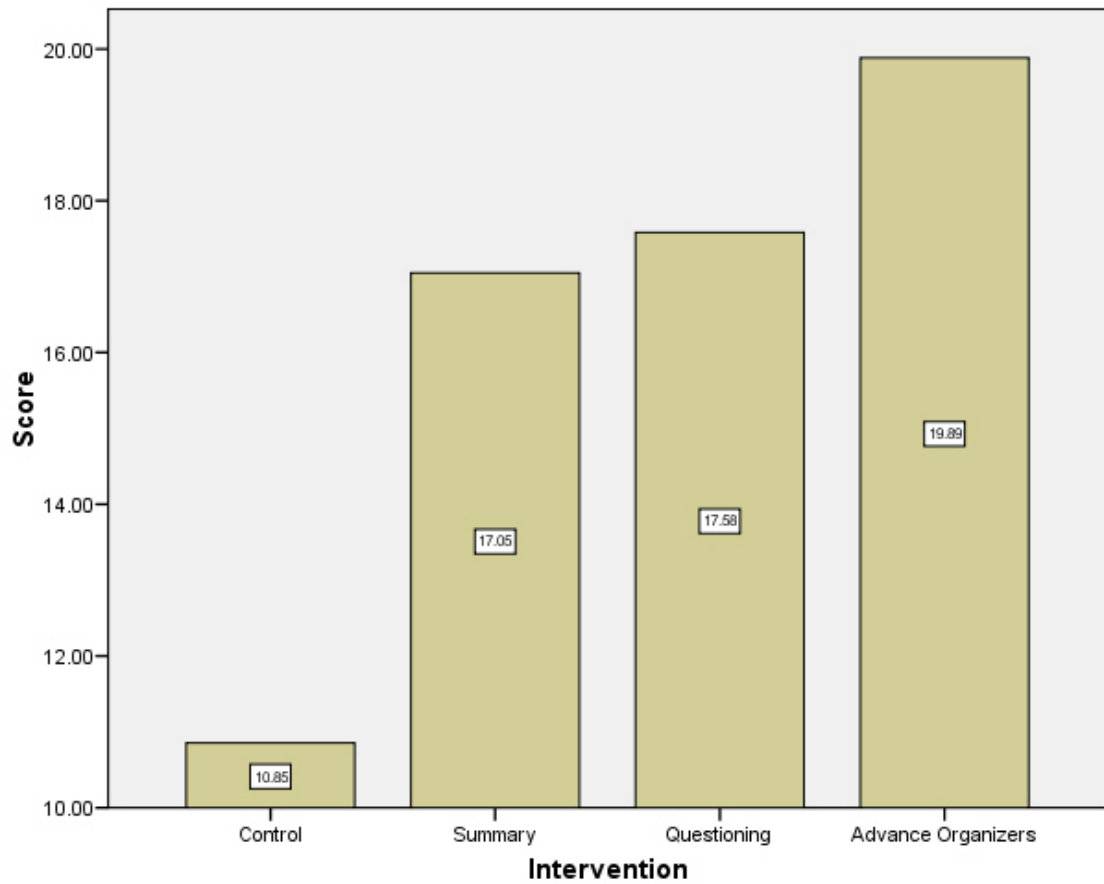


Figure 20. Mean Score for the Interventions and the Control Group across all Trials

Post hoc analysis of test scores using the Dunnett t-test revealed that all of the experimental interventions have outperformed the control group on test scores across all trials (see Table 10).

Table 10.

Means and Pairwise Comparisons of the Control and the Interventions

Intervention (Mean Test Score)	Control 10.8542
Summary 17.049	0.000*
Questioning 17.583	0.000*
Advance Organizer 19.885	0.000*

\*Significant at 0.05 using Dunnett t-test

Again, there was a significant effect for trials,  $F(2, 160) = 152.837, p = 0.000$ , see

Figure 21 for the performance of the different interventions on the trials.

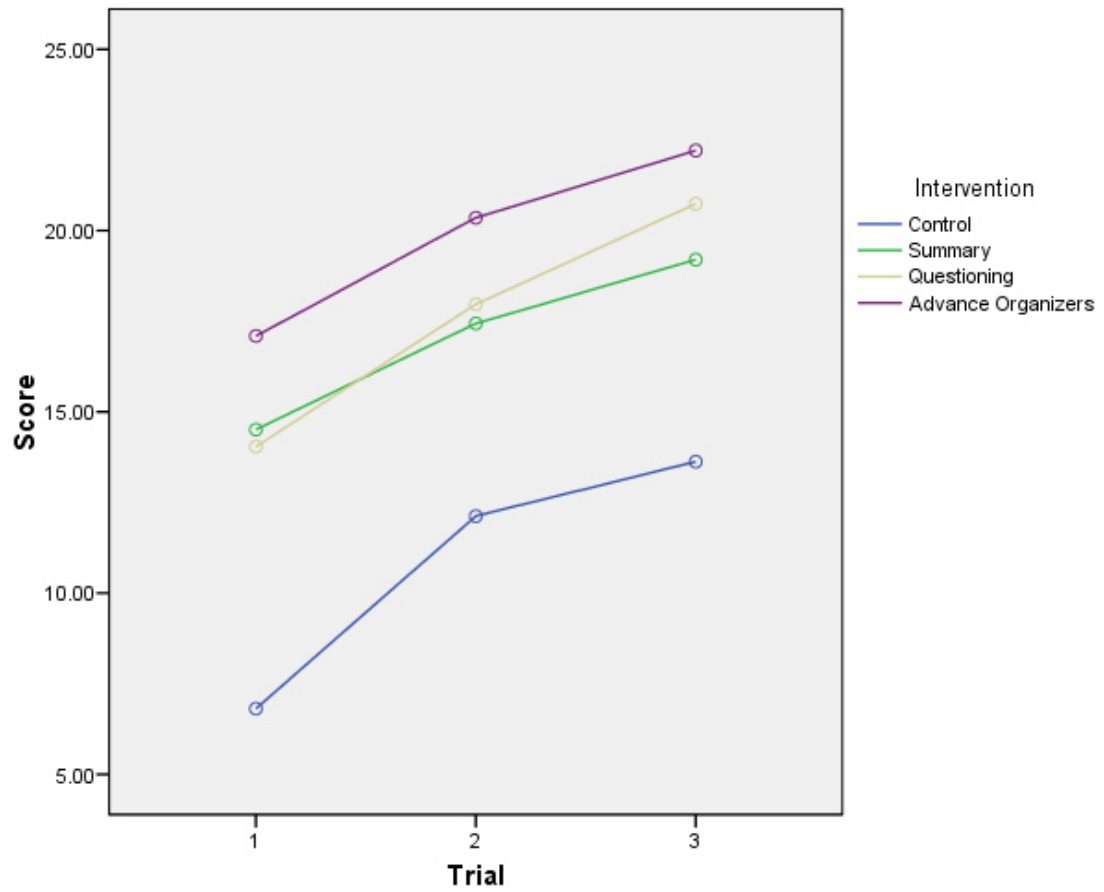


Figure 21. Mean Score on the Trials

### Control Group & the Treatment Combinations

Another analysis was conducted on test scores between each of the treatment combinations and the control group. A two-way mixed effects ANOVA (7\*3) with the seven conditions as the between subjects factor and trials as the within subjects factor was performed. The performance measure was the test score (see Table 11).

Table 11.

ANOVA Results for the Control and the Treatment Combinations

Source	df	MS	F	Sig.
Between subjects				
Treatment Combinations	6	73988.587	1523.583	0.000
Error	77	48.562		
Within subjects				
Trials	2	691.240	156.663	0.000
Trials * Treatment Combinations	12	5.950	1.349	.197
Error	154	4.412		

The ANOVA indicated a main effect for the treatment combinations,  $F(6, 77) = 1523.58, p = 0.000$ , (see Figure 22).

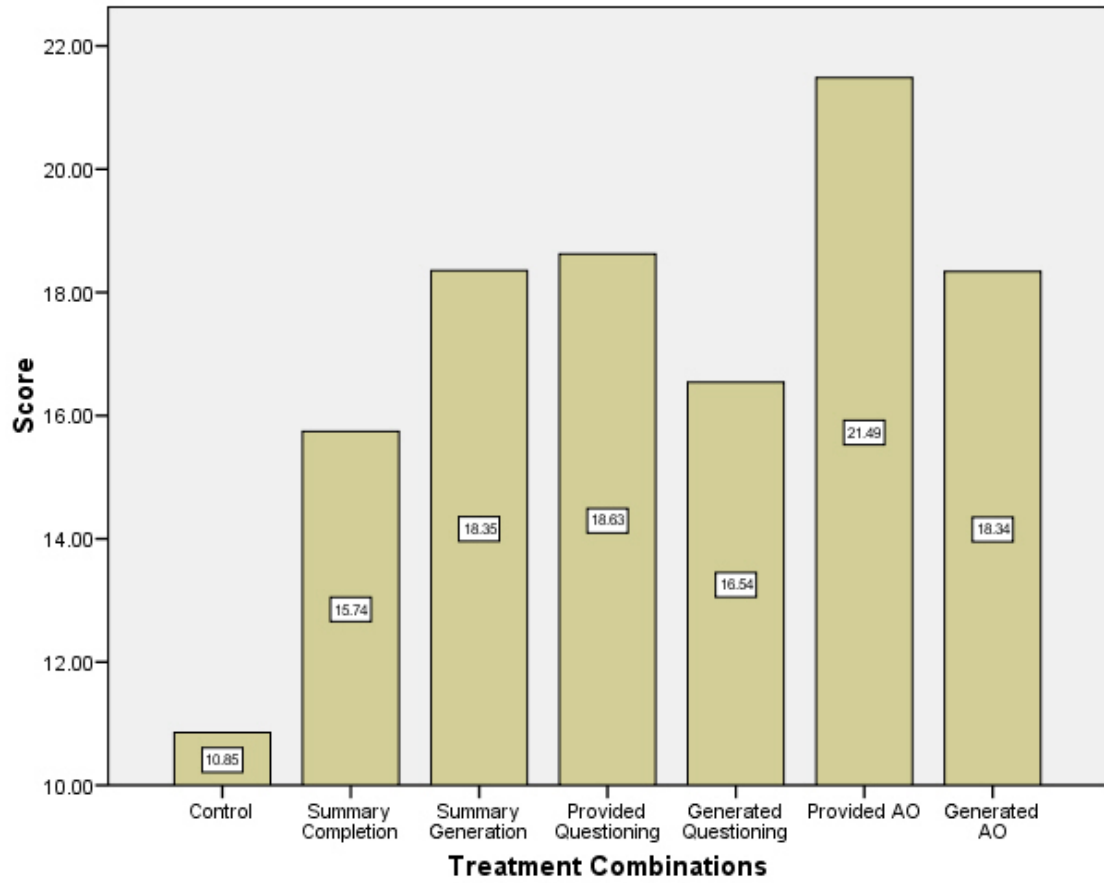


Figure 22. Mean of Score for the Treatment Combinations across all Trials



Further post hoc analysis of test scores using the Dunnett t-test revealed that all the experimental treatment combinations scored significantly higher than the control group. Therefore, further analysis of the training trials will simply investigate the treatment combinations (see Table 12).

Table 12.

Means and Dunnett t-test on Control and Treatment Combinations

Treatment Combinations (Mean Test Score across all Trials)	Control
Summary Completion 15.743	0.010*
Generated Questioning 16.5417	0.002*
Generated Advance Organizers 18.3403	0.000*
Summary Generation 18.3542	0.000*
Provided Questioning 18.6250	0.000*
Provided Advance Organizers 21.4861	0.000*

\*Significant at 0.05 using Dunnett t-test

In addition, there was a main effect for the trials,  $F(2, 154) = 156.663, p = 0.000$ , the mean test score for the groups on each trial is shown in Figure 23.

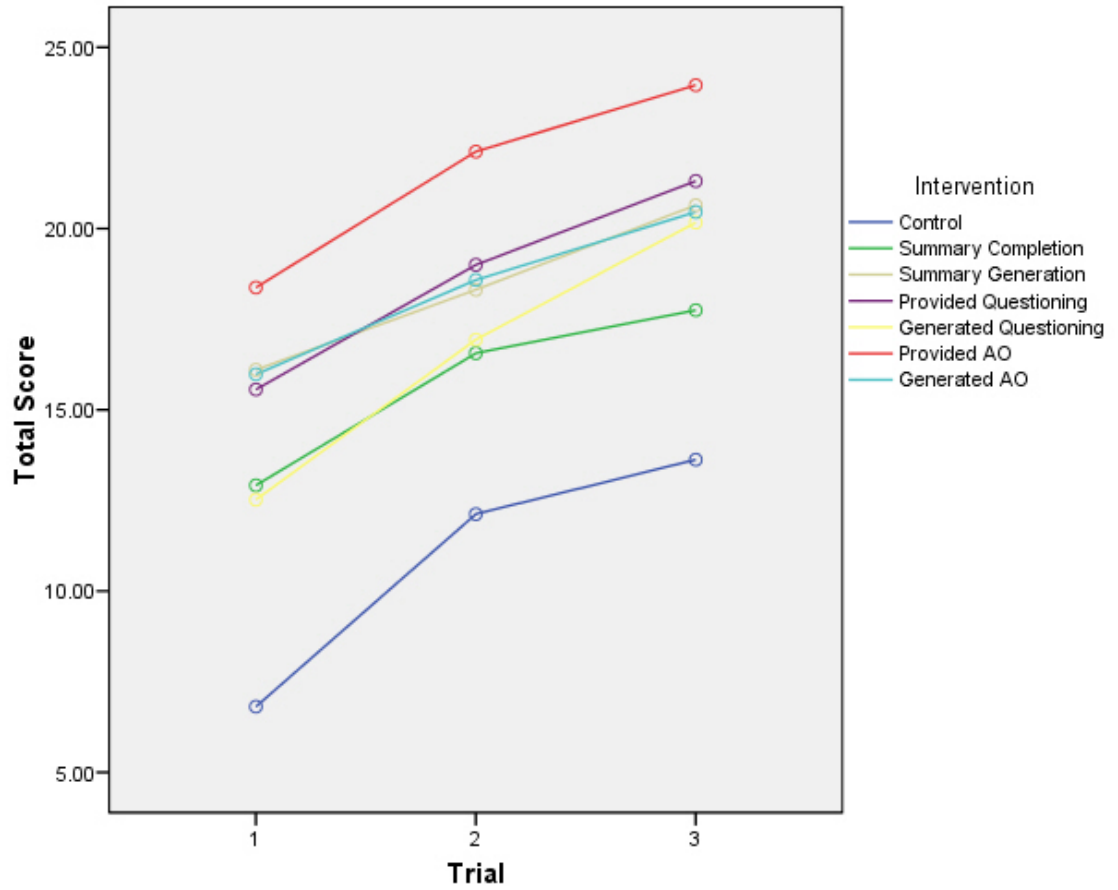


Figure 23. Plot of Means of Score for the Control & Treatment Combinations

An interesting observation can be made by looking at the mean scores (see Table 13). Participants in the control group were learning but at a much slower rate than the experimental groups. For instance, it took the control group three trials to achieve a similar score than the summary completion group attained in their first trial.

Table 13.

Mean Test Score Summary

Treatment Combinations	Trial 1	Trial 2	Trial 3
Control	6.8125	12.1250	13.6250
Summary Completion	12.9167	16.5625	17.7500
Generated Questioning	12.5208	16.9375	20.1667
Generated Advance Organizer	15.9792	18.5833	20.4583
Provided Questioning	15.5625	19.0000	21.3125
Summary Generation	16.1042	18.3125	20.6458
Provided Advance Organizer	18.0000	22.1250	23.9583

### Study Time

An analysis was performed using three-way mixed effects ANOVA (3\*2\*3) with two between subject factors (interventions and level of generation) and one within subjects factor (trials). The dependent measure was the study time on each trial. The ANOVA is shown in Table 14.

Table 14.

ANOVA Results on Study Time for Trial 1-3

Source	df	MS	F	Sig.
Between subjects				
Intervention	2	390635.292	0.653	0.524
Level of Generation	1	23146.741	0.039	0.845
Intervention * Level of Generation	2	365079.810	0.610	0.546
Error	66	598669.003		
Within subjects				
Trials	2	12622365.389	52.467	0.000
Trials * Intervention	4	554195.701	2.304	0.062
Trials * Level of Generation	2	77177.574	0.321	0.726
Trials * Int. * Level of Generation	4	290853.498	1.209	0.310
Error (Trials)	132	240575.318		

The ANOVA results indicated that the only significant difference for the study time was for the trials,  $F(2, 132) = 52.467, p = 0.000$ . This was expected, as participants tend to need less time going through the trials (see Figure 24).

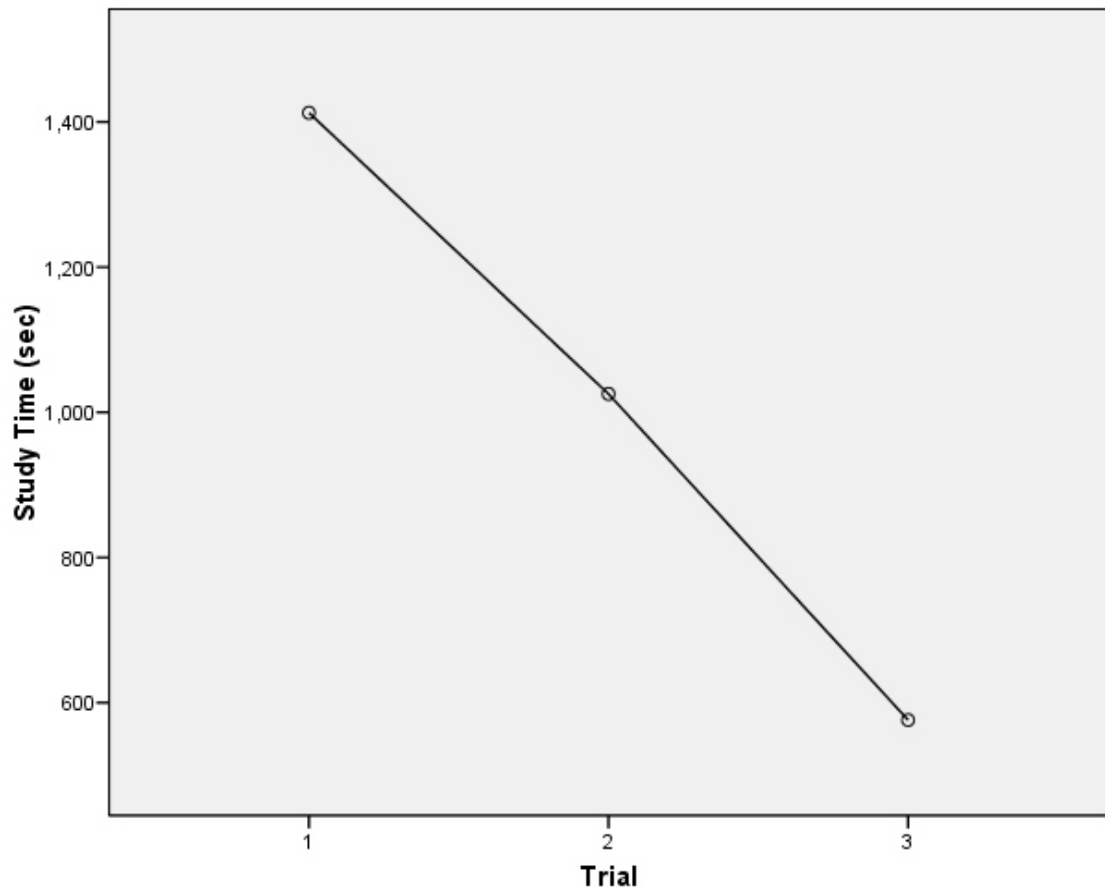


Figure 24. Plot for the Study Time on the Trials across all Interventions

Further analysis was performed to evaluate study time between the control group and the three interventions. A (4\*3) mixed design ANOVA with a between subjects factor of the control and the interventions and a within subjects factor of the trials was performed (see Table 15).

Table 15.

ANOVA Results for Study Time

Source	df	MS	F	Sig.
Between subjects				
Interventions	3	1277426.702	1.886	.139
Error	80	677172.383		
Within subjects				
Trials	2	10885579.433	46.588	.000
Trials * Interventions	6	807277.851	3.455	.003
Error	160	233658.169		

The ANOVA indicated that there was no differences in the study time between the interventions and the control group.

As expected the study time was significant for the trials,  $F(2, 160) = 46.588$ ,  $p = 0.00$ , (see Figure 25)

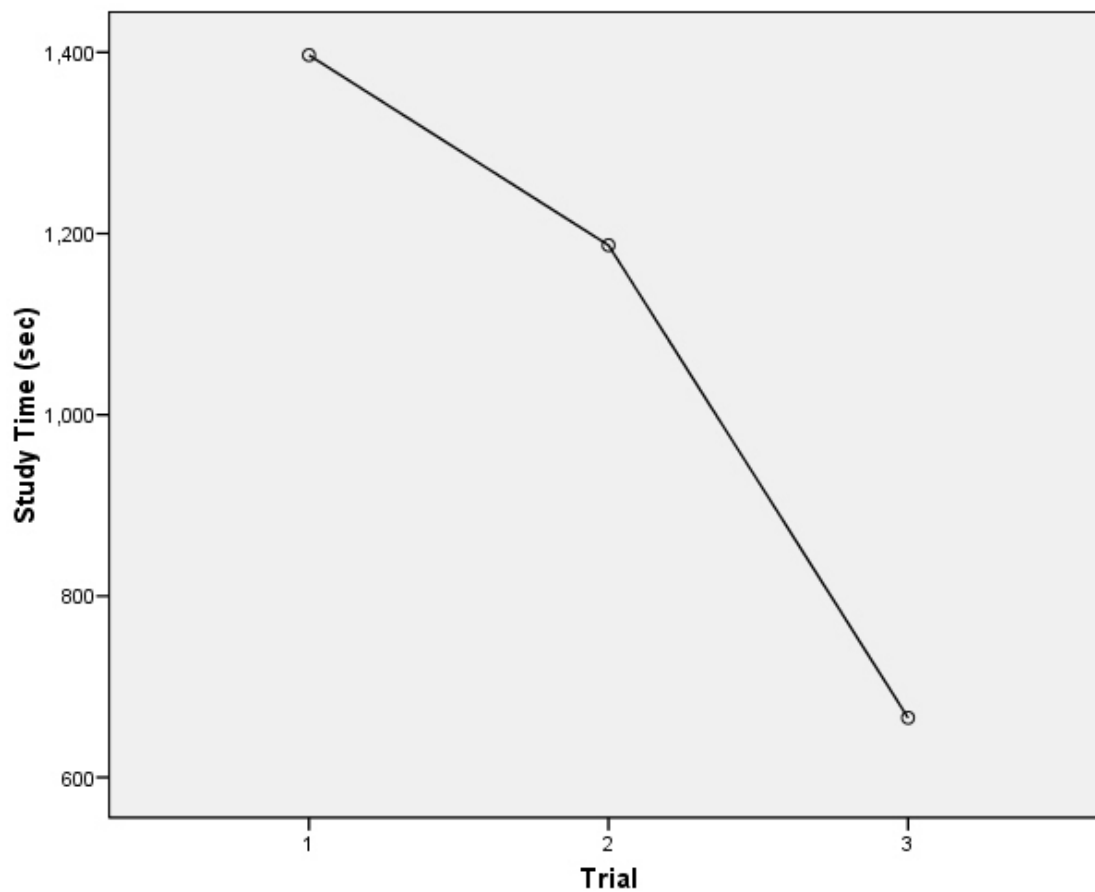


Figure 25. Means of Study Time for the Trials across all interventions

The interaction between the trials and the interventions was also significant,  $F(6, 160) = 3.455, p = 0.003$ . This interaction is shown in Figure 26 where interventions exchanged position in terms of the study time required to interact with the curriculum as subjects progressed from one trial to another.

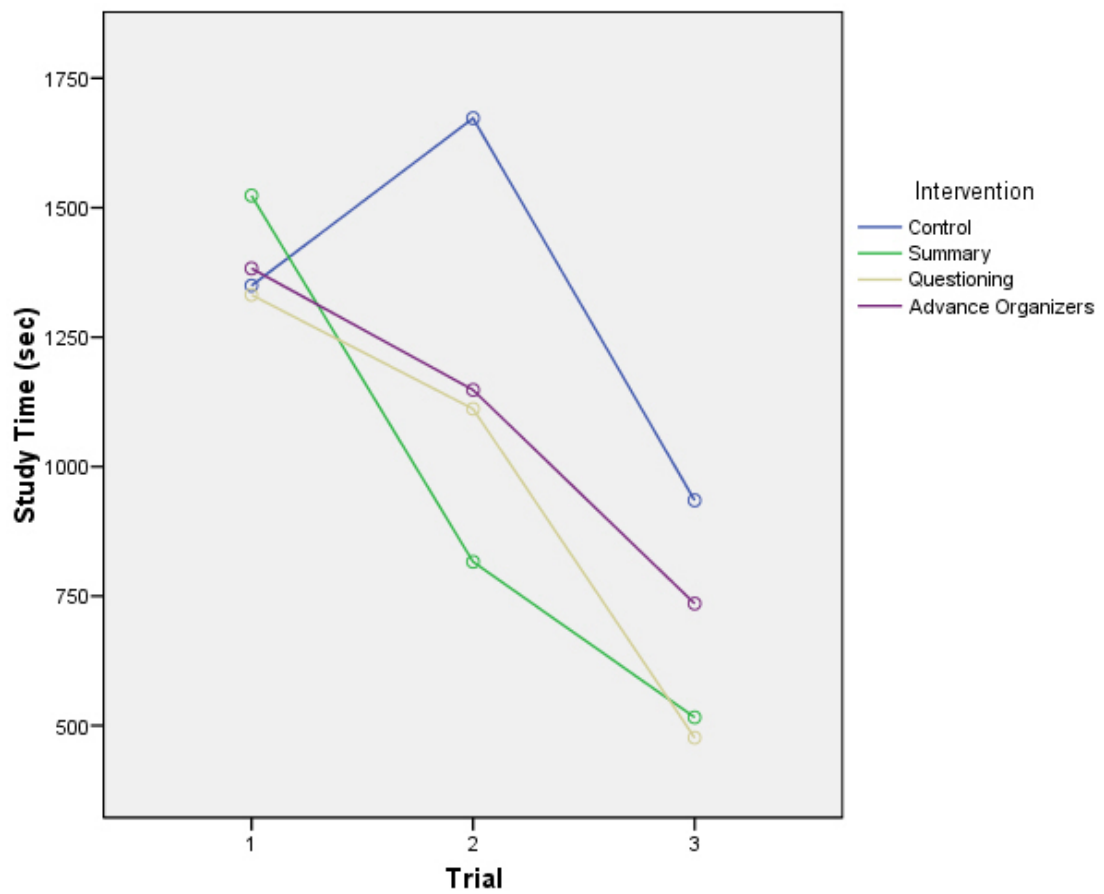


Figure 26. Interaction of Trials and Interventions on Study Time



### **Time on Elaboration**

A (3\*2\*3) mixed effect ANOVA with two between subject factors (interventions and level of generation) and a within subject factor of the trials was performed. The dependent measure was the time needed to elaborate on each trial (see Table 16).

Table 16.

#### ANOVA Results for Time on Elaboration

Source	df	MS	F	Sig.
Between subjects				
Intervention	2	4067734.222	18.418	0.000
Level of Generation	1	9315511.338	42.179	0.000
Intervention * Level of Generation	2	2244590.574	10.163	0.000
Error	66	220859.011		
Within subjects				
Trials	2	7022538.375	96.916	0.000
Trials * Intervention	4	127051.576	1.753	0.142
Trials * Level of Generation	2	1233693.560	17.026	0.000
Trials * Int. * Level of Generation	4	751269.817	10.368	0.000
Error (Trials)	132	72460.050		

The ANOVA indicated a main effect for intervention on the elaboration time,  $F(2, 66) = 18.418, p = 0.000$ , (see Figure 27).

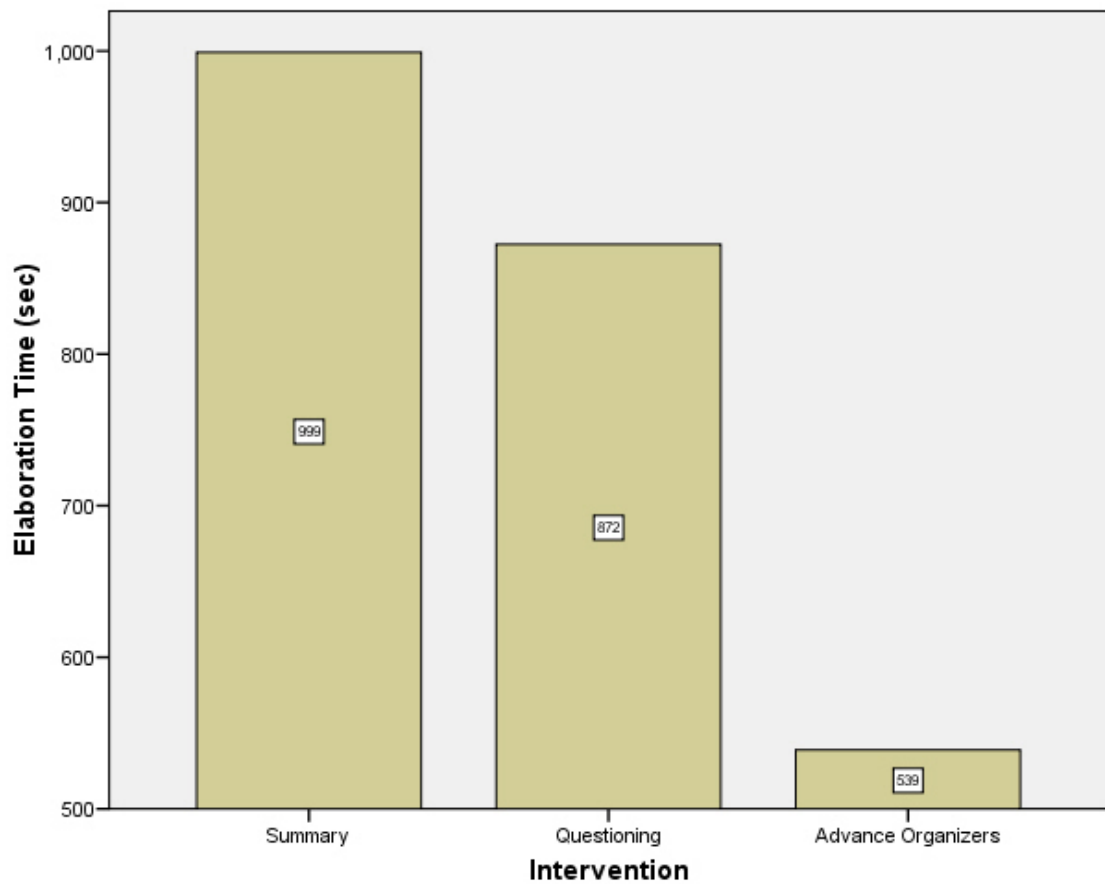


Figure 27. Mean Elaboration Time for the Interventions across all Trials

Using the Tukey HSD to perform the pairwise comparisons, resulted in a significant difference for the time required to elaborate for both the questioning intervention and the summary intervention as compared to the advance organizers intervention, across all trials (see Table 17).

Table 17.

Means and Sig. Values for Pairwise Comparisons on Elaboration Time

	Advance Org. 538.903	Questioning 872.458	Summary 999.014
Advanced Org. 538.903	-----	0.000*	0.000*
Questioning 872.458		-----	0.246
Summary 999.014			-----

\* Significant at 0.05 using Tukey HSD

The results also indicated a significant effect for the level of generation,  $F(1, 66) = 42.179, p = 0.000$ , since the low generative prompts required less time to produce their elaborations (see Figure 28).

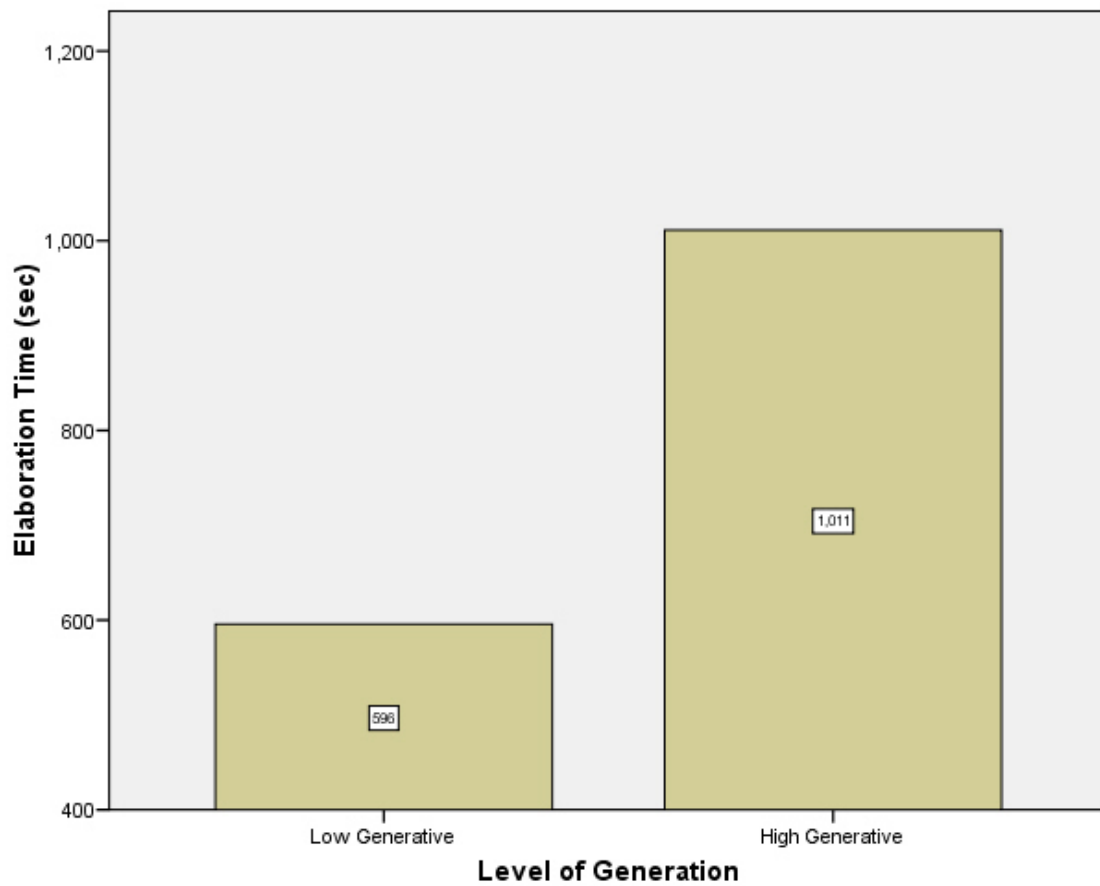


Figure 28. Plot for Elaboration Time for the Level of Generation

Moreover, there was a significant effect for the trials,  $F(2, 132) = 96.916$ ,  $p = 0.000$ , (see Figure 29).

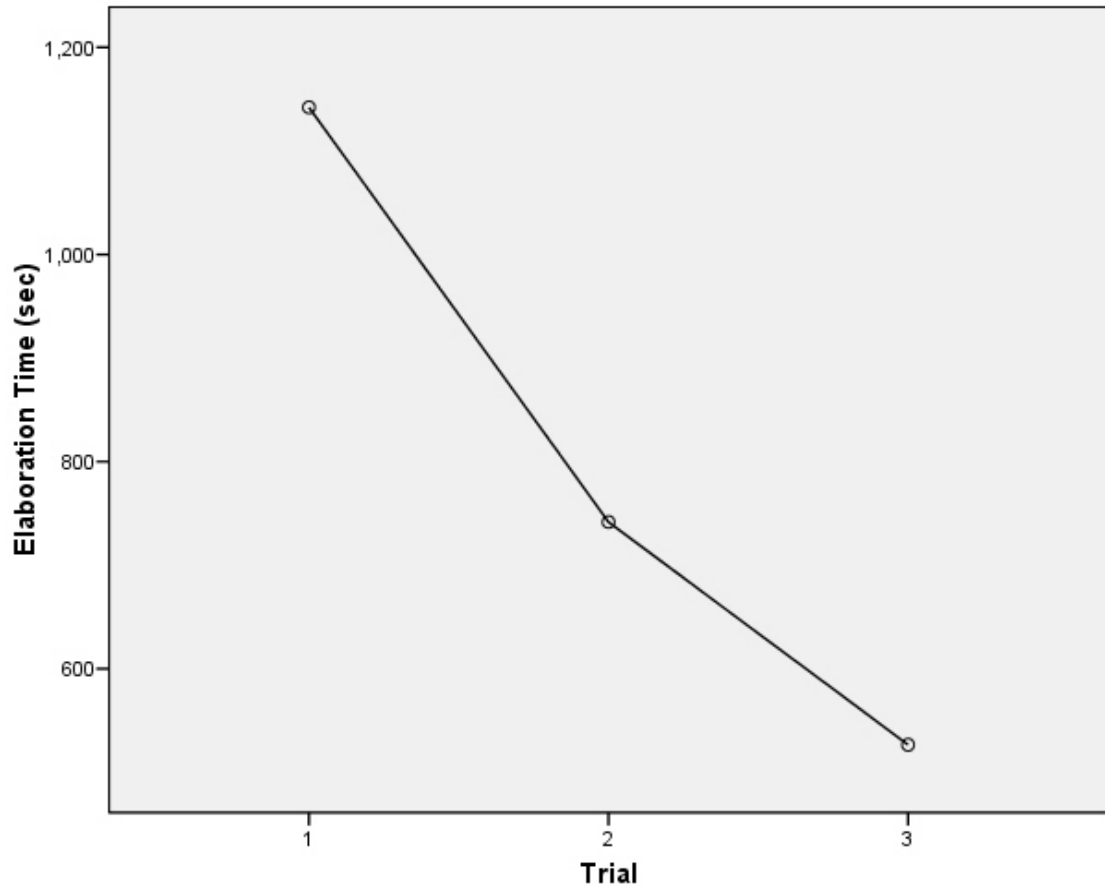


Figure 29. Plot for Elaboration Time for the Trials across all Interventions

Figure 30 presents a graphical display of the mean elaboration time for the different interventions during the three trials.

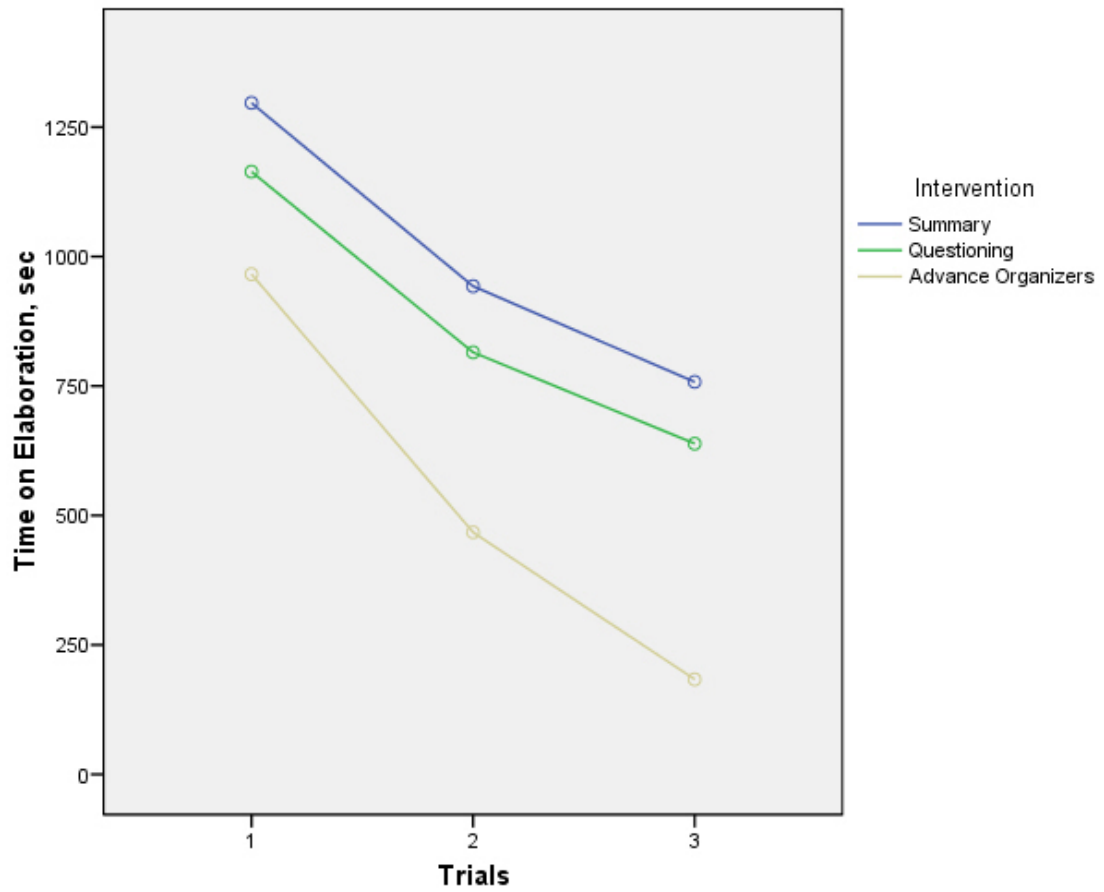


Figure 30. Plot of Means of Elaboration Time for the Trials

Several interactions were significant. The two-way interaction between intervention \* level of generation was significant,  $F(2, 66) = 10.163, p = 0.000$ , (see Figure 31).

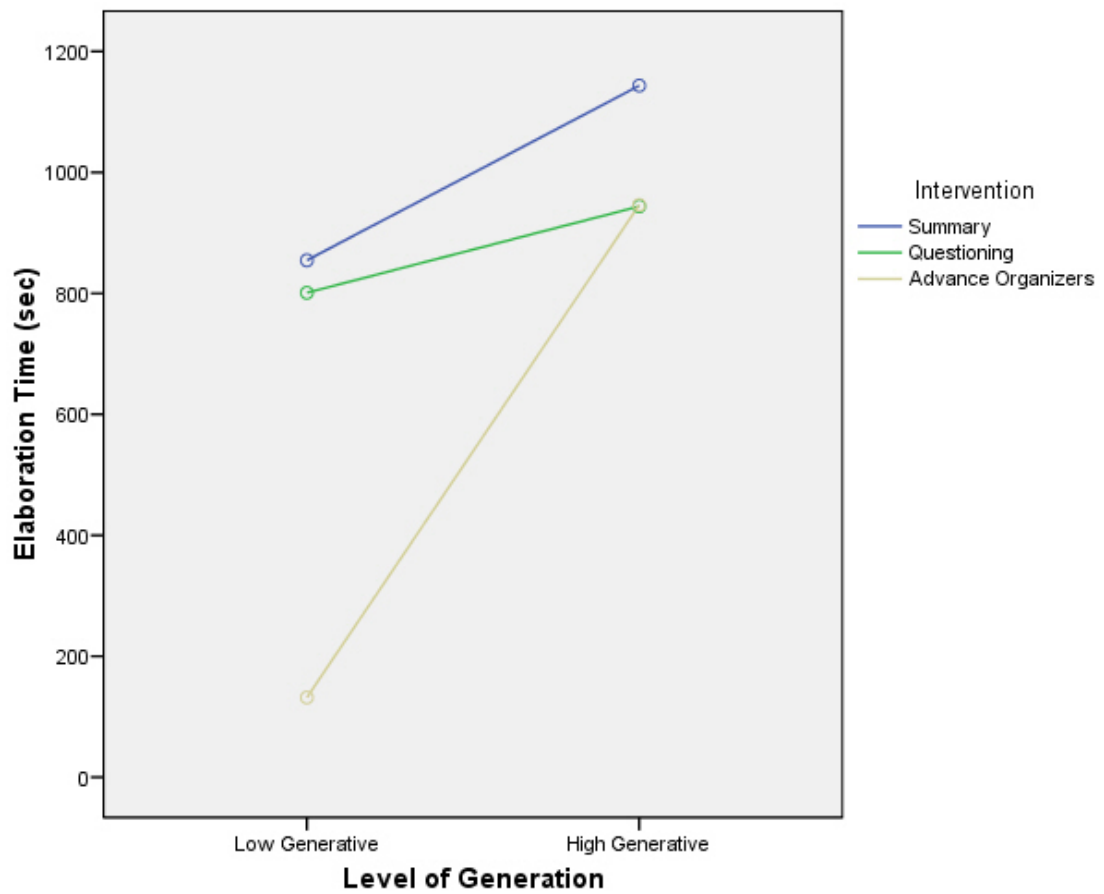


Figure 31. Interaction between Intervention & Level of Generation

In addition, the two-way interaction between trials \* level of generation was significant,  $F(2, 132) = 17.026$ ,  $p = 0.000$ , (see Figure 32).

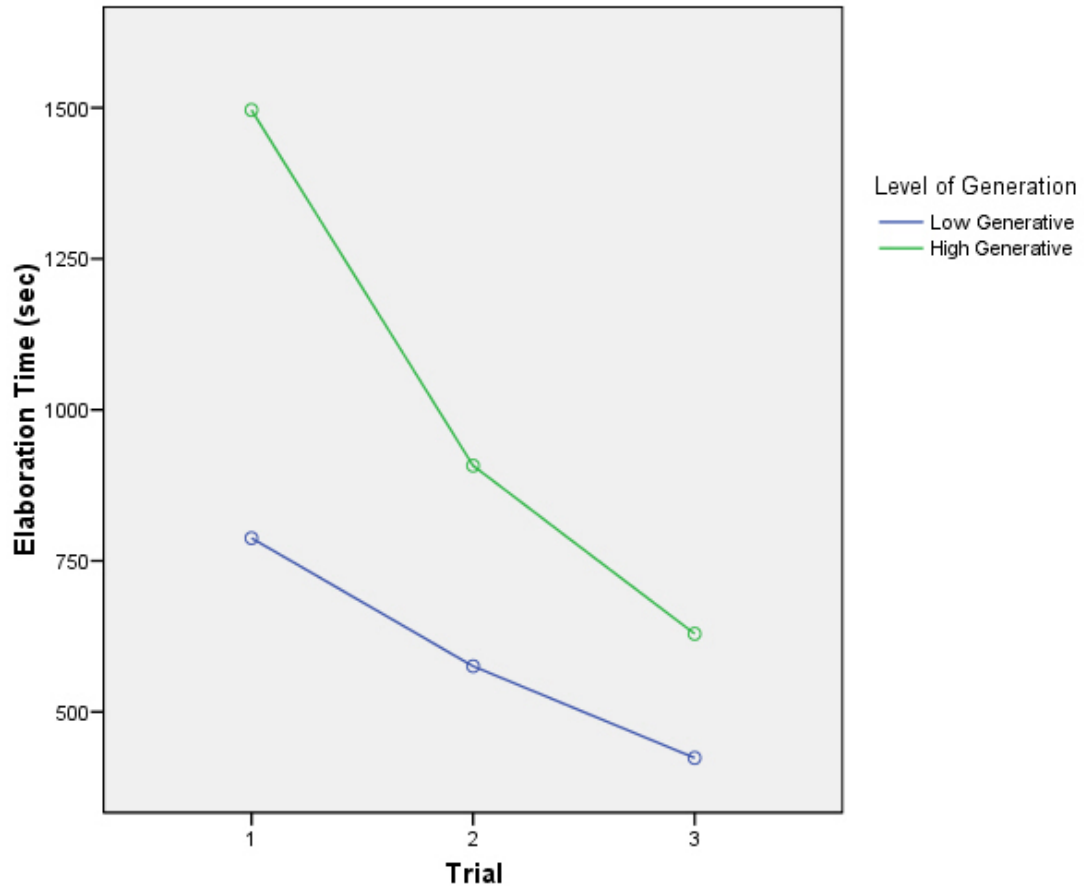


Figure 32. Interaction between Trial & Level of Generation



Last, the three-way interaction between trials \* interventions \* level of generation was significant,  $F(4, 132) = 10.368, p = 0.000$ , see Figure 33.

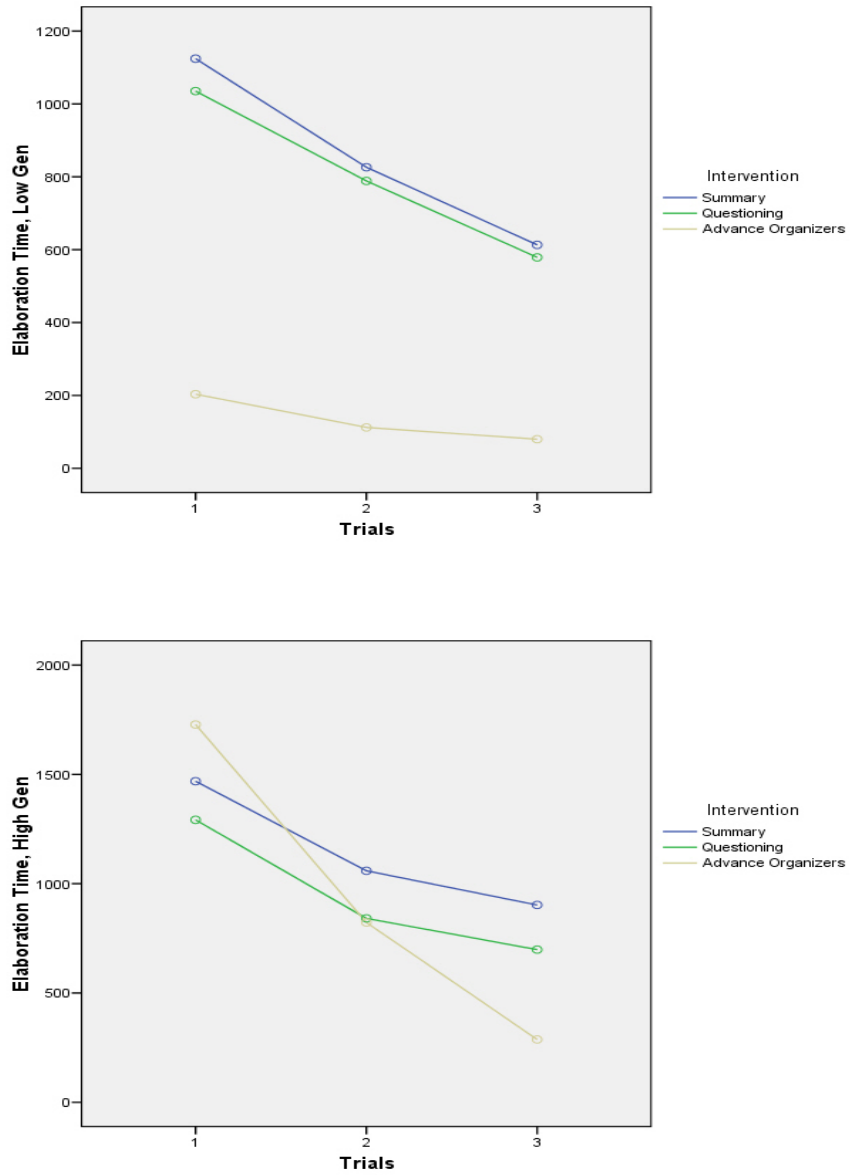


Figure 33. Interaction of Trials \* Interventions \* Level of Generation

Further investigation of the elaboration time was performed by looking at treatment combinations. A mixed effects ANOVA (6\*3) with the treatment combinations as the between subjects factor and the trials as the within subjects factor was performed (see Table 18).

Table 18.

ANOVA Results on Elaboration Time for the Treatment Combinations

Source	df	MS	F	Sig.
Between subjects				
Treatment Combinations	5	4388032.186	19.868	0.000
Error	66	220859.011		
Within subjects				
Trials	2	7022538.375	96.916	0.000
Trials * Treatment Combinations	10	598067.269	8.254	0.000
Error	132	72460.050		

The ANOVA indicated a main effect for the treatment combinations,  $F(5, 66) = 19.868, p = 0.000$ , (see Figure 34).

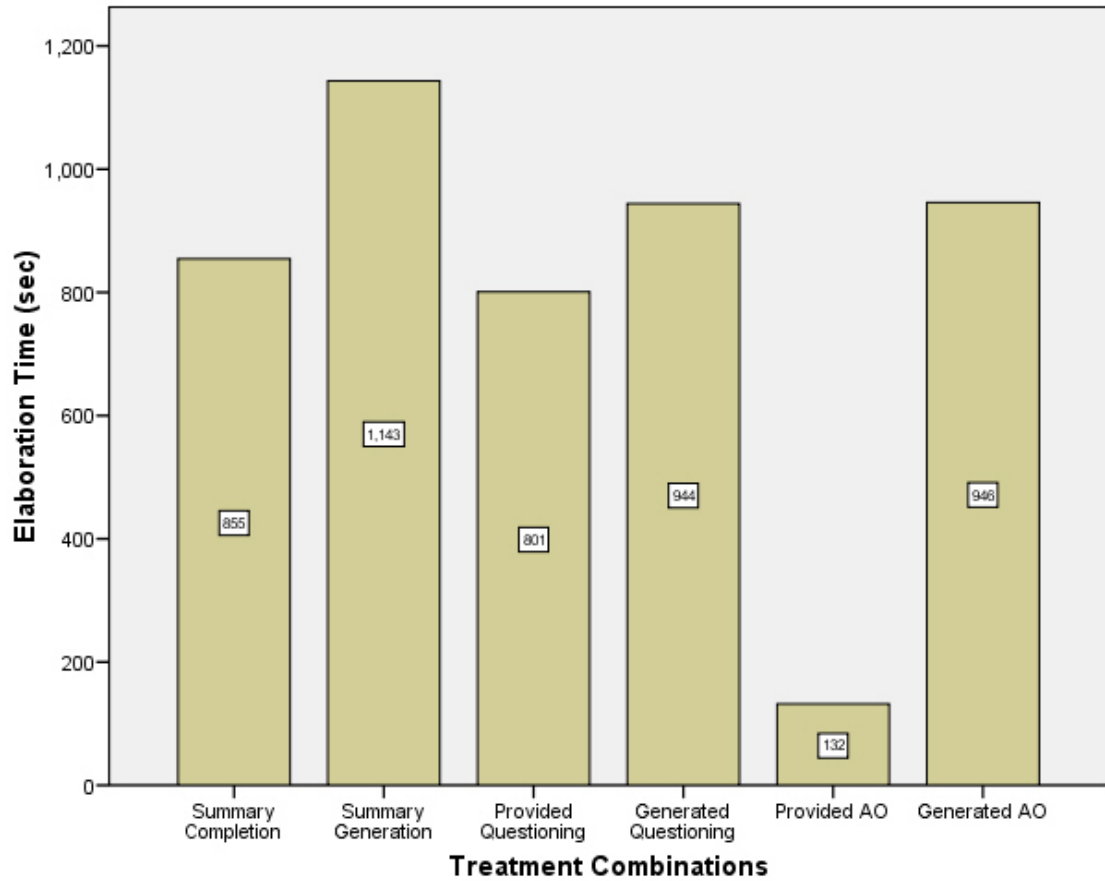


Figure 34. Means of Elaboration Time for the Treatment Combinations across Trials

Post hoc analysis of the elaboration time using the Tukey HSD indicated that the mean time on elaboration for the three trials was lower for the provided advance organizer than the rest of the groups. In addition, the mean elaboration time for the summary generation group was higher than the provided questioning group (see Table 19).

Table 19.

Means and Pairwise Comparisons for Elaboration Time across all Trials

Tr. Combinations (mean elab. Time)	Pro. AO 131.75	Prov. Q 801.00	S. Com 854.61	Gen. Q. 943.92	Ge. AO 946.06	S. Gen. 1143.42
Pro. AO 131.75	-----	0.000*	0.000*	0.000*	0.000*	0.000*
Prov. Q 801.00		-----	0.997	0.789	0.779	0.033*
S. Com 854.61			-----	0.965	0.962	0.110
Gen. Q. 943.92				-----	1.000	0.472
Ge. AO 946.06					-----	0.484
S. Gen. 1143.42						-----

\*Significant at 0.05 using Tukey HSD

In addition, the trials were significant,  $F(2, 132) = 96.916, p = 0.000$ , (see Figure 35).

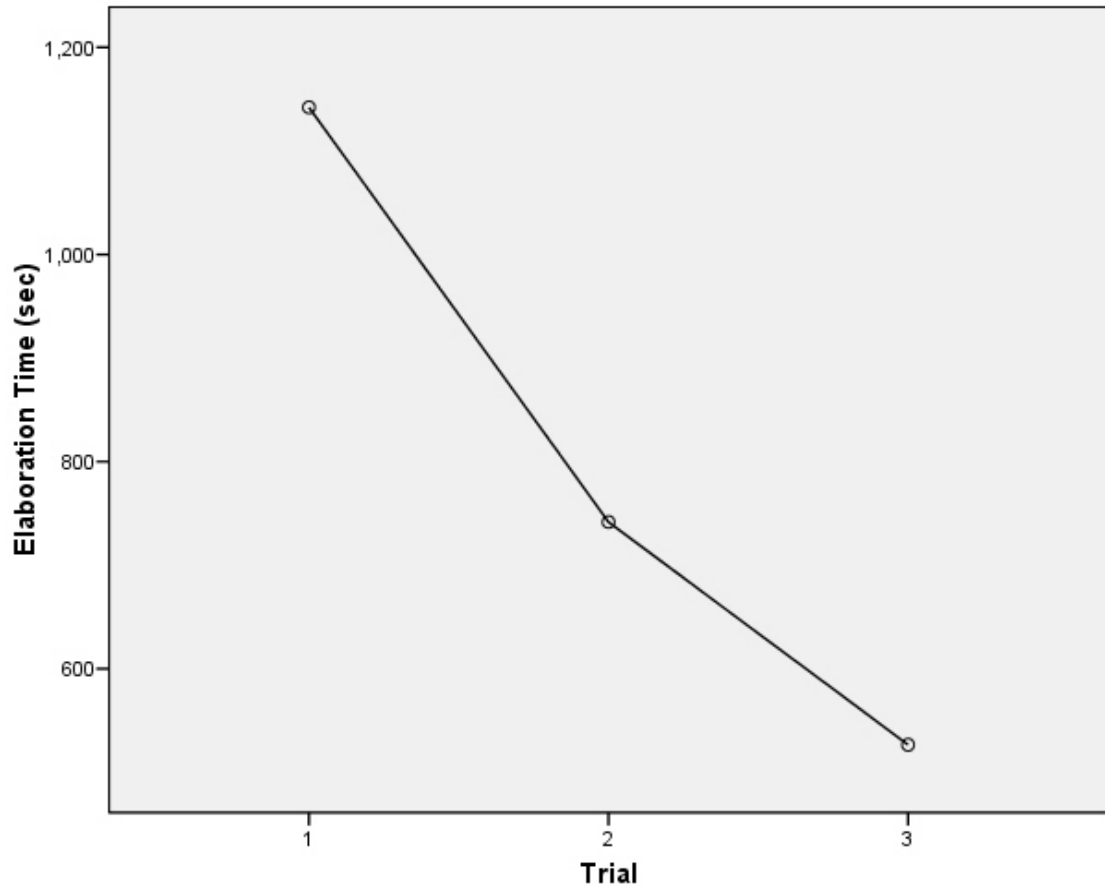


Figure 35. Elaboration Time for the Trials across all Treatment Combinations

Last, the interaction between the trials and the treatment combinations was also significant with,  $F(10, 132) = 8.254, p = 0.000$ , (see Figure 36).

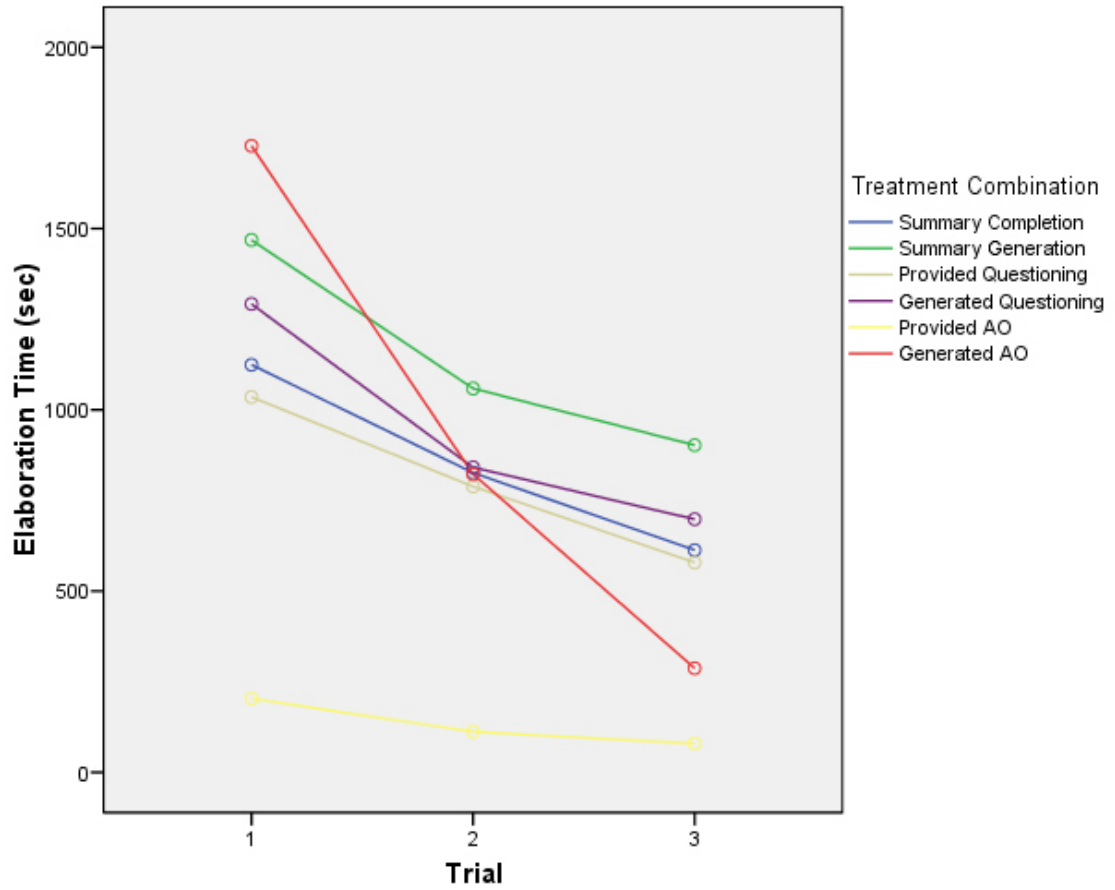


Figure 36. Means of Elaboration Time for the Treatment Combinations

Table 20 presents the time needed by participants to elaborate on the material for each trial.

Table 20.

Mean Time for Elaboration in the Trials (min)

Treatment Combinations	Trial 1	Trial 2	Trial 3
Provided Advance Organizer	3.38	1.86	1.33
Provided Questioning	17.25	13.13	9.65
Summary Completion	18.73	13.77	10.22
Generated Questioning	21.53	14.02	11.63
Summary Generation	24.47	17.65	15.03
Generated Advance Organizer	28.8	13.7	4.78

### Analysis of Gain Scores

To examine the learning gains throughout the trials, a two between (intervention and level of generation) and one within (trials) mixed effects ANOVA (3\*2\*3) analysis was performed (see Table 21).

Table 21.

ANOVA Results for the Learning Gains

Source	df	MS	F	Sig.
Between subjects				
Intervention	2	18.129	3.001	0.057
Level of Generation	1	2.042	0.338	0.563
Intervention * Level of Generation	2	20.928	3.465	0.037
Error	66	6.040		
Within subjects				
Trials	2	3757.009	284.322	0.000
Trials * Intervention	4	30.204	2.286	0.063
Trials * Level of Generation	2	10.883	0.824	0.441
Trials * Int. * Level of Generation	4	30.510	2.309	0.061
Error (Trials)	132	13.214		



The ANOVA indicated a main effect for the trials,  $F(2, 132) = 284.322$ ,  $p = 0.000$ , suggesting that most of the learning occurred in trial 1 (see Figure 37).

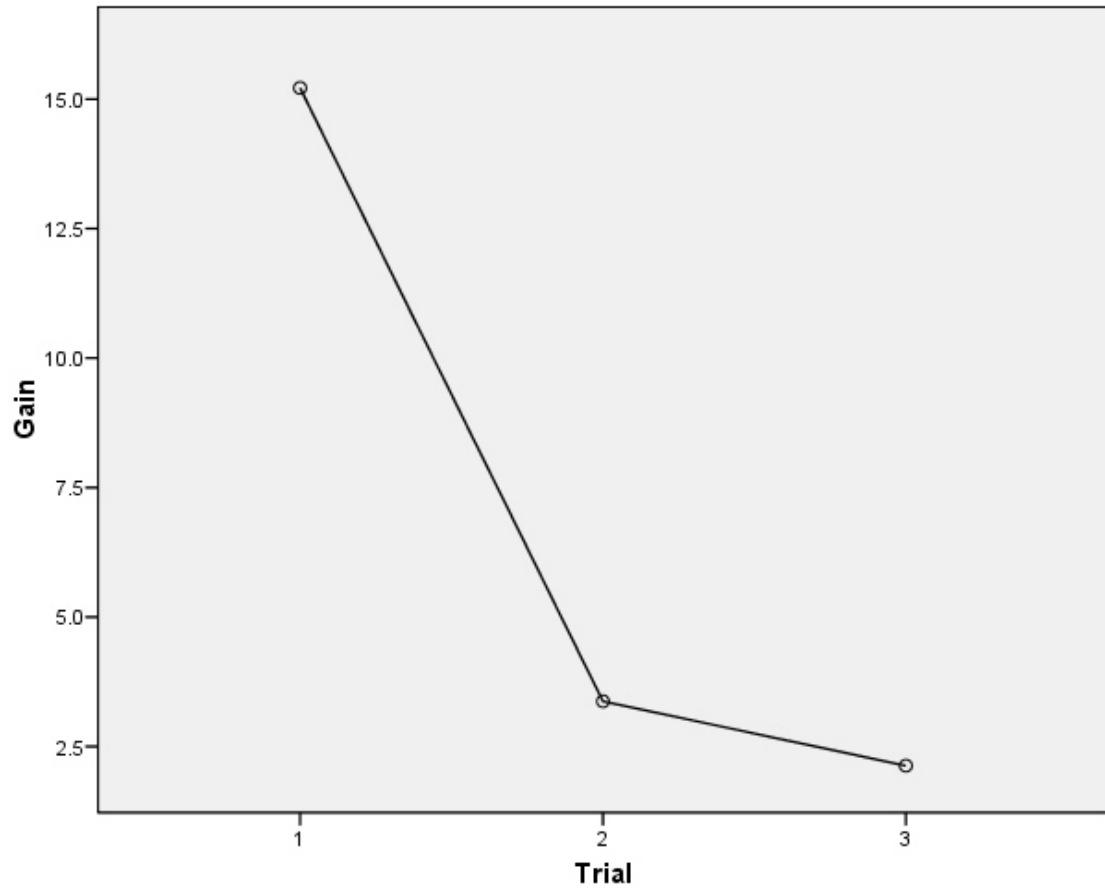


Figure 37. Plot of Means of Gain on the Trials across Interventions

The two-way interaction between the intervention \* level of generation was also significant,  $F(2, 66) = 3.465$ ,  $p = 0.037$ , (see Figure 38).

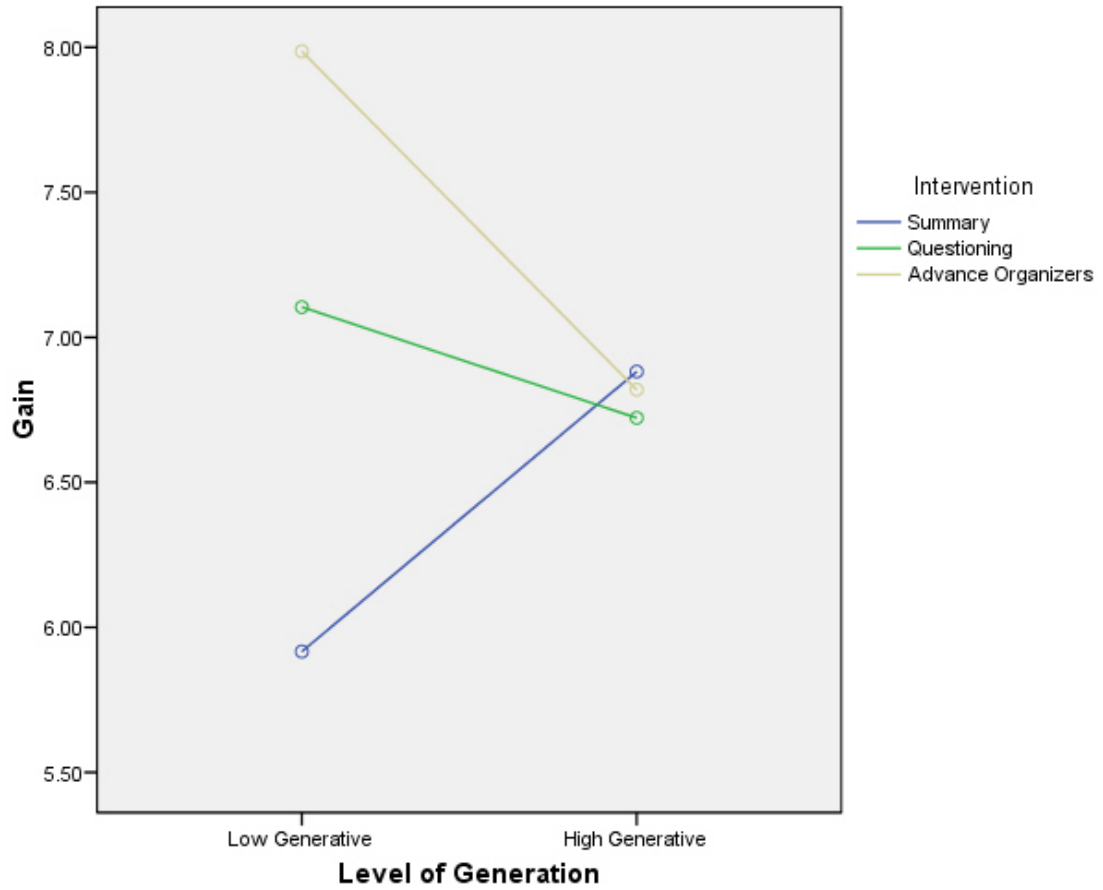


Figure 38. Intervention & Level of Generation on Gain

The analysis revealed that interventions and the trials \* interventions were close to the established alpha level, but not significant (see Figure 39).

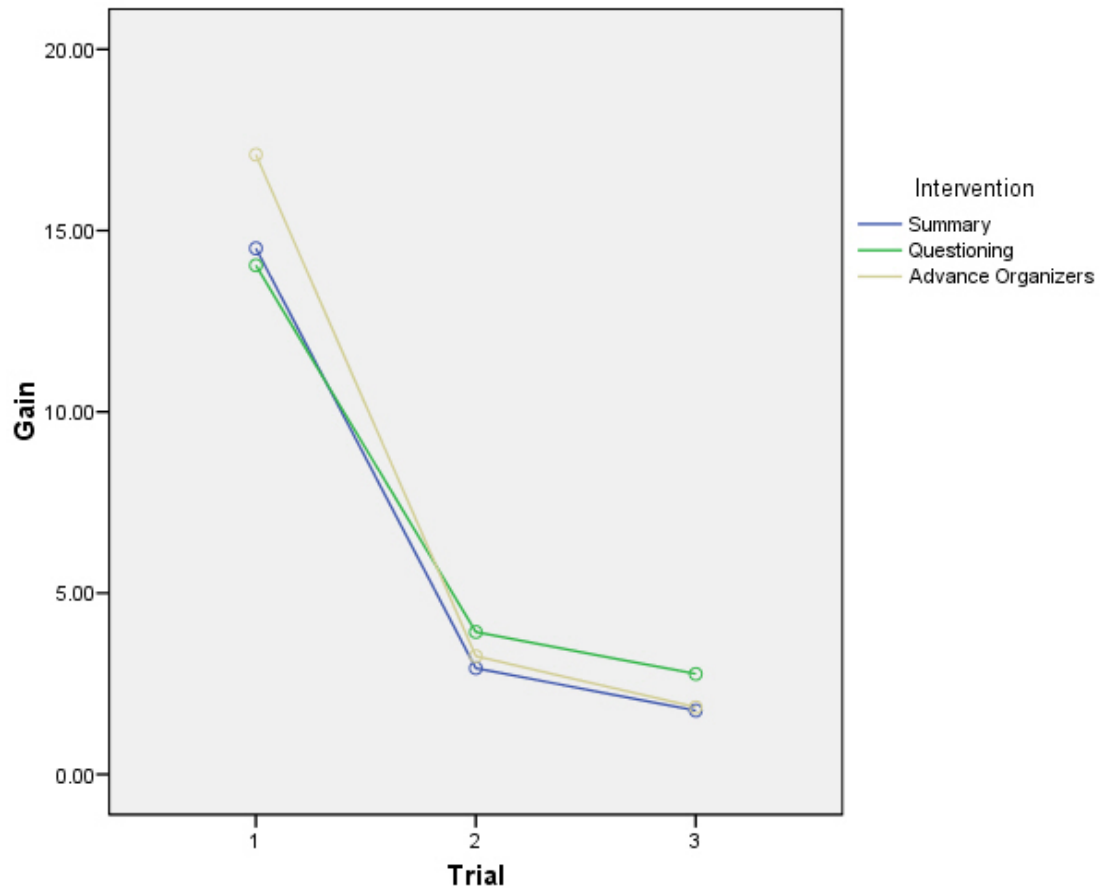


Figure 39. Gains for the Interventions across the Trials

Further analysis was conducted on learning gain differences between the three interventions and the control group. A mixed design ANOVA (4\*3) with the control and the experimental conditions as the between subjects factor and the trials as the within subjects factor was performed. The ANOVA results are shown in Table 22.

Table 22.

ANOVA Results for Learning Gains between Control & Interventions

Source	df	MS	F	Sig.
Between subjects				
Intervention	3	69.540	10.396	.000
Error	80	6.689		
Within subjects				
Trials	2	2731.948	203.820	.000
Trials * Intervention	6	119.584	8.922	.000
Error (Trial)	160	13.404		

The ANOVA results indicated a significant effect for the intervention,  $F(3, 80) = 10.396$ ,  $p = 0.000$ , see Figure 40 for a graphical display for the gains for the interventions and the control group across all trials.

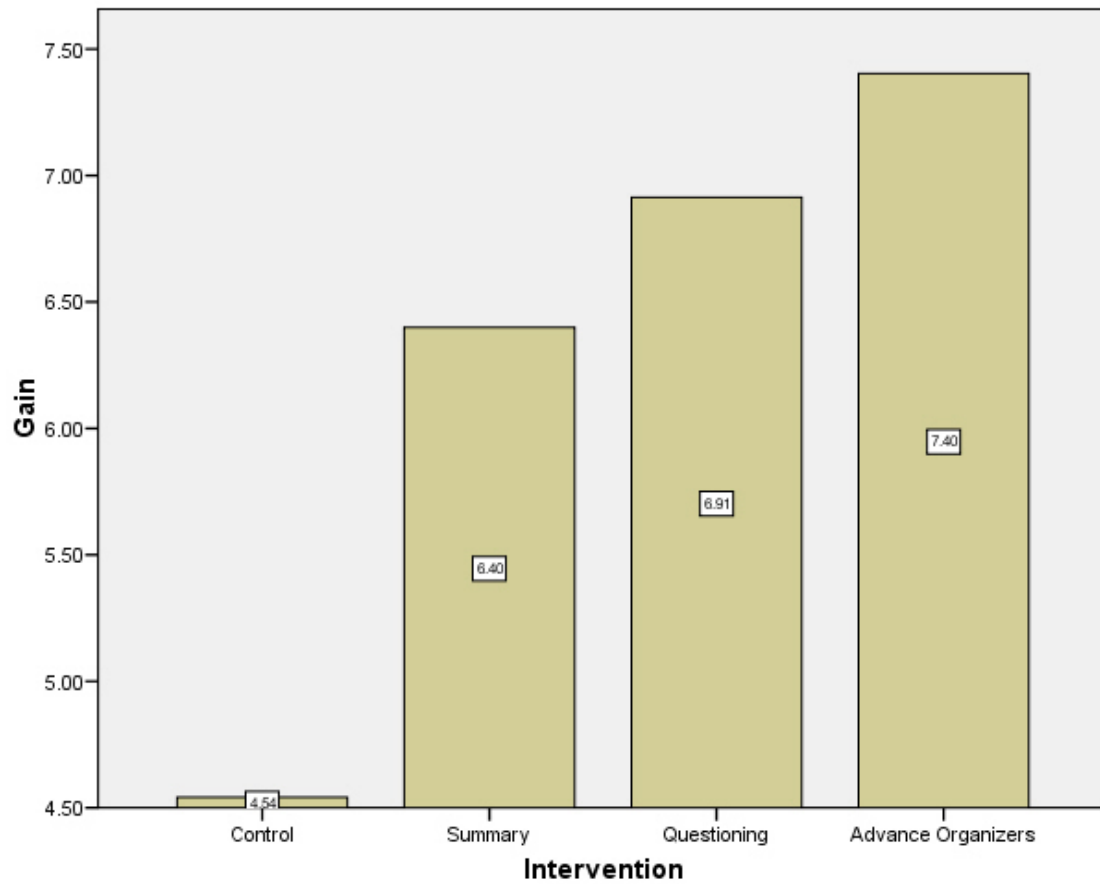


Figure 40. Gains for the Interventions and the Control Group across all Trials

Post hoc analysis of learning gain using Dunnett t-test revealed that all of the experimental interventions have outperformed the control group (see Table 23).

Table 23.

Gains and Pairwise Comparisons of the Control and the Interventions

Intervention (Mean Gain)	Control
Summary 6.399	4.542 0.001*
Questioning 6.913	0.000*
Advanced Org. 7.403	0.000*

\*Significant at 0.05 using Dunnett t-test

Again, there was a significant main effect for the trials,  $F(2, 160) = 203.820$ ,  $p = 0.000$ , see Figure 41 for the performance of different intervention on the trials.

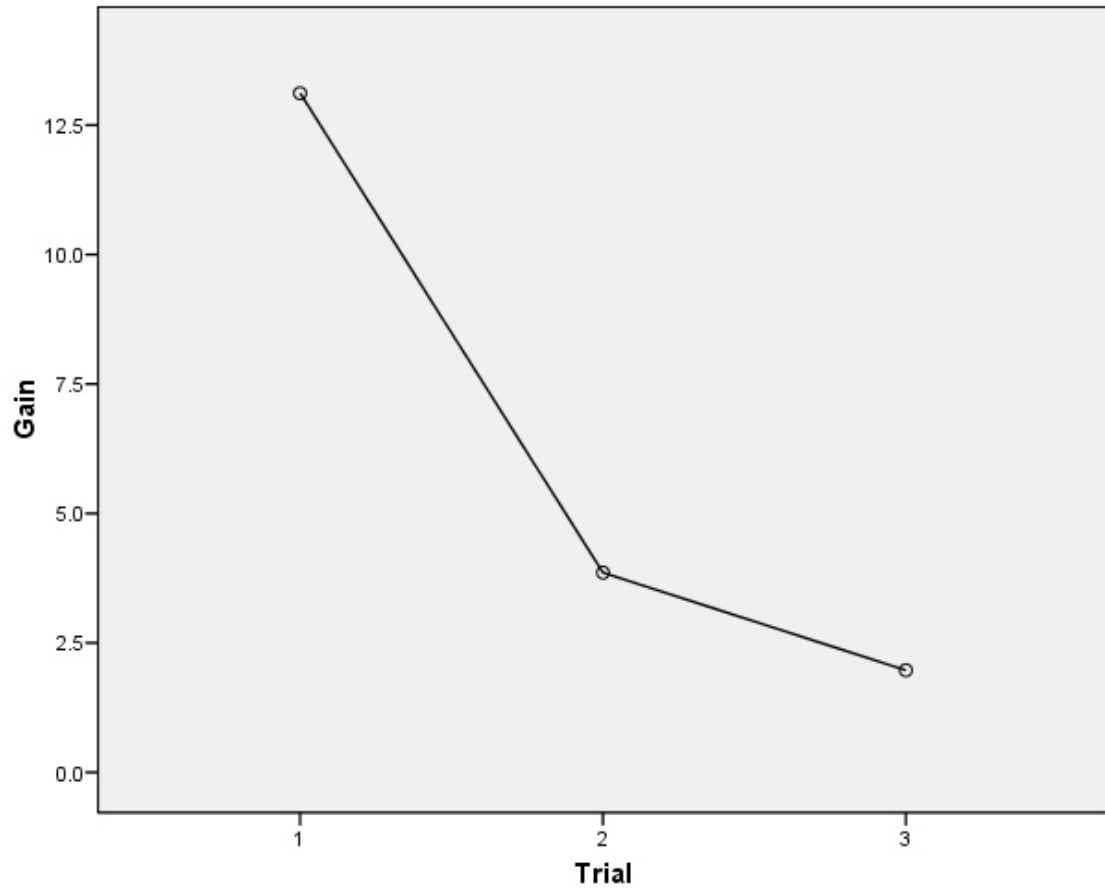


Figure 41. Mean Gain on the Trials across the Interventions

Last, there was a significant main effect for the trials \* interventions,  $F(2, 160) = 8.922, p = 0.000$ , as the learning gain for the control group spanned trial 1 and 2 (see Figure 42).

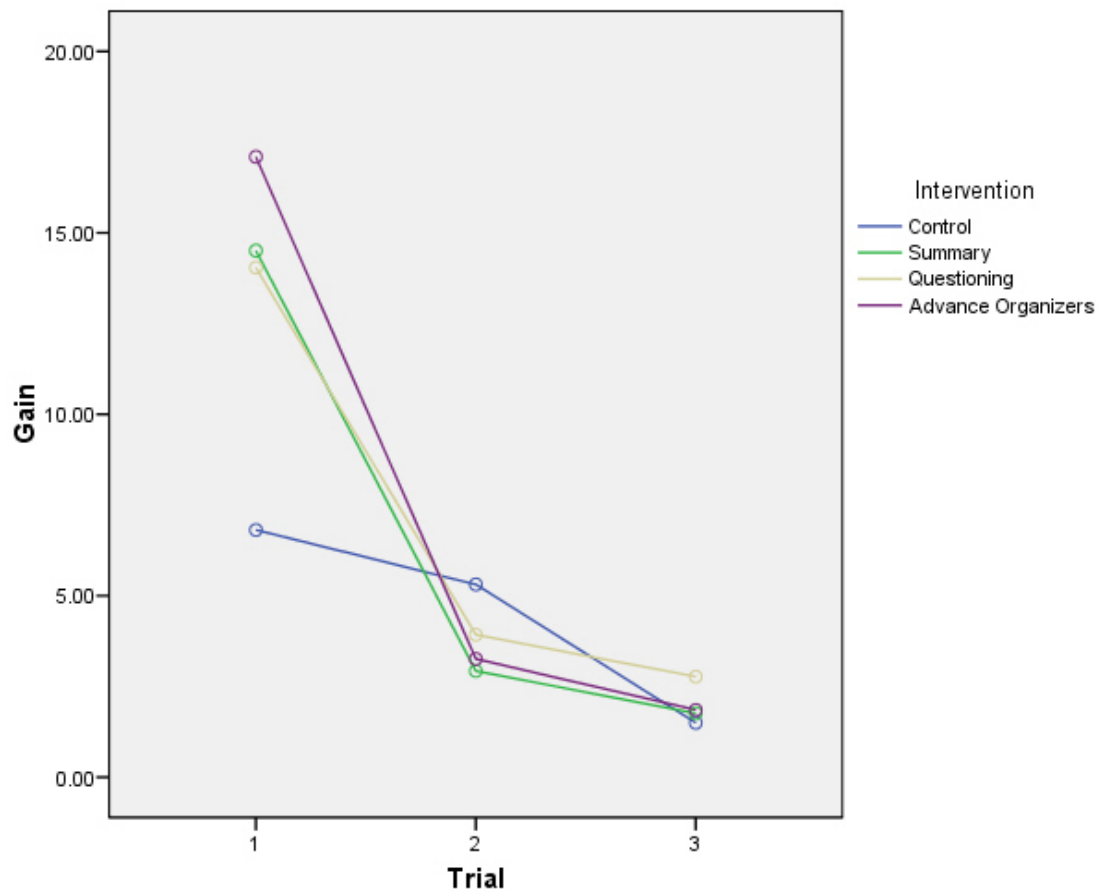


Figure 42. Interaction of Trial and Intervention on Gain



### **Treatment Combinations and Trial 1**

As most of the learning commenced on trial one, a closer look at the performance of the treatment combinations was worthwhile. An ANOVA was performed to measure the performance of the subjects based on the test score relative to the treatment combinations. A one-way ANOVA of the mean score is shown in Table 24; it shows a main effect of the treatment combinations,  $F(6, 77) = 10.741, p = 0.000$ .

Table 24.

ANOVA Results on Test Score on Trial 1

Source	df	MS	F	Sig.
Treatment Combinations	6	169.876	10.741	0.000
Within Groups	77	15.816		
Total	83			

The mean test score pertaining to each treatment combination is shown graphically in Figure 43.

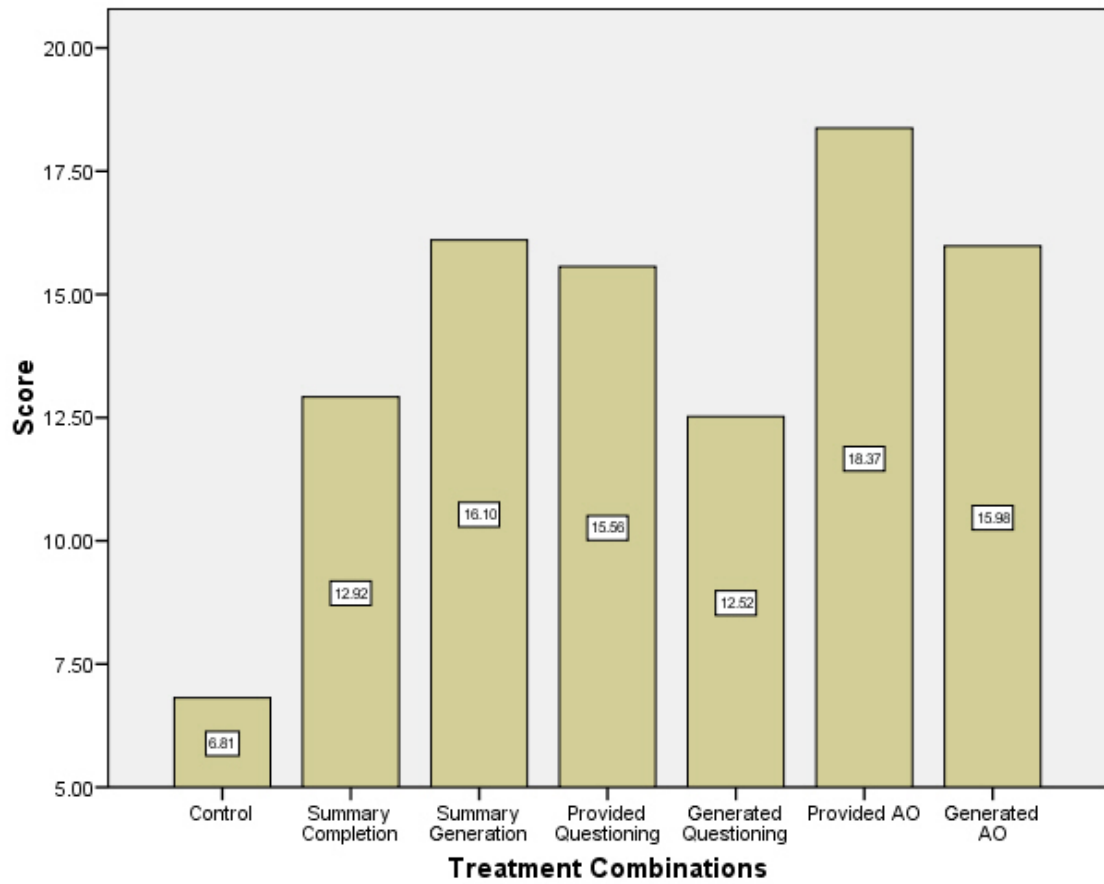


Figure 43. Plot of Means of Score in Trial 1

Further post hoc analysis of the test scores using Tukey HSD revealed that all experimental groups scored significantly higher than the control group. In addition, the provided advance organizers group scored higher than both the generated questions group ( $p = 0.010$ ) and the summary completion group ( $p = 0.020$ ) (see Table 25).

Table 25.

Mean Test Score on Trial 1 and Sig. Values for Pairwise Comparisons

	Control 6.8125	Gen. Q. 12.5208	S. Com. 12.9167	Prov. Q. 15.5625	Ge. AO 15.9792	S. Gen. 16.1042	Prov. AO 18.3750
Control 6.8125	-----	0.013*	0.006*	0.000*	0.000*	0.000*	0.000*
Gen. Q. 12.5208		-----	1.000	0.504	0.346	0.304	0.010*
S. Com. 12.9167			-----	0.664	0.496	0.446	0.020*
Prov. Q. 15.5625				-----	1.000	1.000	0.597
G. AO 15.9792					-----	1.000	0.758
S. Gen. 16.1042						-----	0.801
Prov. AO 18.3750							-----

\* Significant at 0.05 using Tukey HSD

Further analysis was performed on elaboration time for trial 1. An ANOVA was performed to measure the performance of participants based on the elaboration times relative to the treatment combinations. The one-way ANOVA of the elaboration time is shown in Table 26; it shows a significant main effect of the treatment combinations,  $F(6, 77) = 10.741, p = 0.000$ .

Table 26.

ANOVA Results for Elaboration Time on Trial 1

Source	df	MS	F	Sig.
Treatment Combinations	5	3278026.958	16.149	.000
Within Groups	66	202983.274		
Total	71			

The mean elaboration time pertaining to each treatment combination is shown graphically in Figure 44.

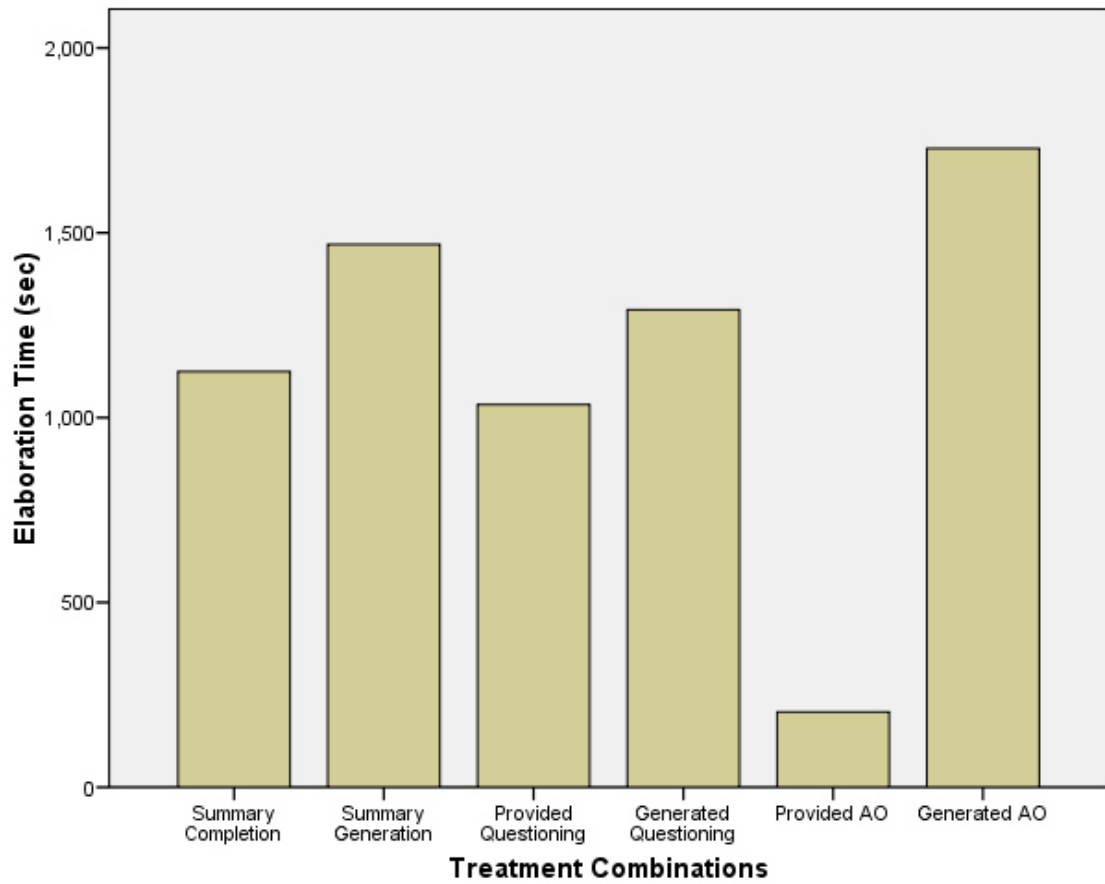


Figure 44. Plot of Means of Elaboration Time in Trial 1

Further post hoc analysis of the elaboration times using Tukey HSD revealed that the mean elaboration time was significantly lower for the provided advance organizer than the rest of the treatment combinations. In addition, elaboration time for the generated advance organizer was significantly higher than the provided questioning ( $p = 0.005$ ) and the summary completion ( $p = 0.020$ ), (see Table 27).

Table 27.

Mean Elaboration Time on Trial 1 and Pairwise Comparisons

	Prov. AO 203.33	Prov. Q. 1035.42	S. Com. 1124.33	Gen. Q. 1292.08	S. Gen. 1468.75	Ge. AO 1728.33
Prov. AO 203.33	-----	0.000*	0.000*	0.000*	0.000*	0.000*
Prov. Q. 1035.42		-----	0.997	0.730	0.187	0.005*
S. Com. 1124.33			-----	0.942	0.428	0.020*
Gen. Q. 1292.08				-----	0.929	0.181
S. Gen. 1468.75					-----	0.720
Ge. AO 1728.33						-----

\*Significant at 0.05 using Tukey HSD

## Retention

To measure the effect of the interventions on retention, a two between (interventions and level of generation) ANOVA was performed on decay between trial 3 and trial 4 (retention trial). The decay was measured by the difference in test scores between trial 3 and the retention test. The two-way ANOVA indicated that there were no effects neither for the intervention nor for the level of generation on the decay in remembering the curriculum. The ANOVA results are displayed in Table 28.

Table 28.

ANOVA Results on Retention on Trial 3 & 4

Source	df	MS	F	Sig.
Intervention	2	8.774	1.376	0.260
Level of Generation	1	0.031	0.005	0.944
Intervention * Level of Generation	2	19.198	3.011	0.056
Error	66	6.376		
Total	72			

Hence, there was no effect on retention between the knowledge construction interventions.

Figure 46 shows a graphical display of mean test score on trial 3 and trial 4 (retention trial)

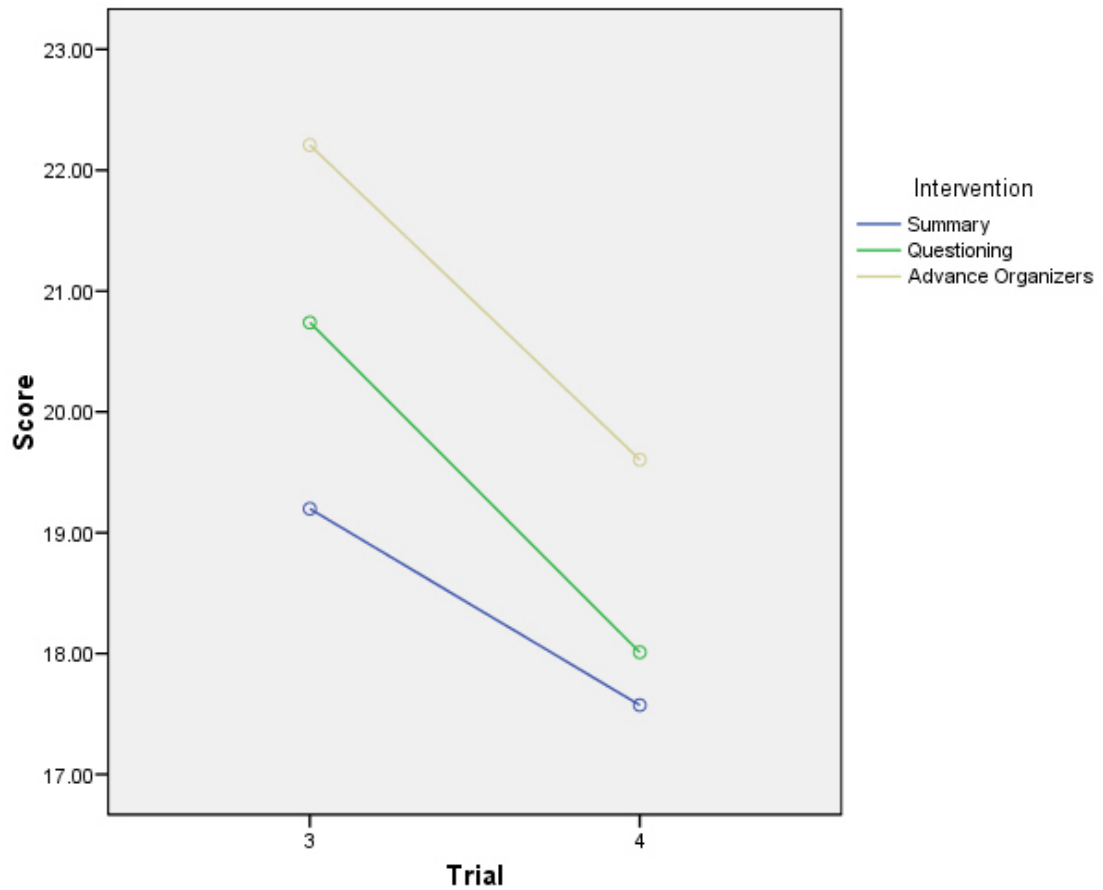


Figure 45. Plot of Score on Test for Trail 3 and the Retention



It was useful to look at the interaction between the intervention and the level of generation since it was not far from the criteria established,  $F(2, 66) = 3.011, p = 0.056$ . Figure 47 shows the interaction where the low generative advance organizers seem to remember the curriculum better than the high generative advance organizers.

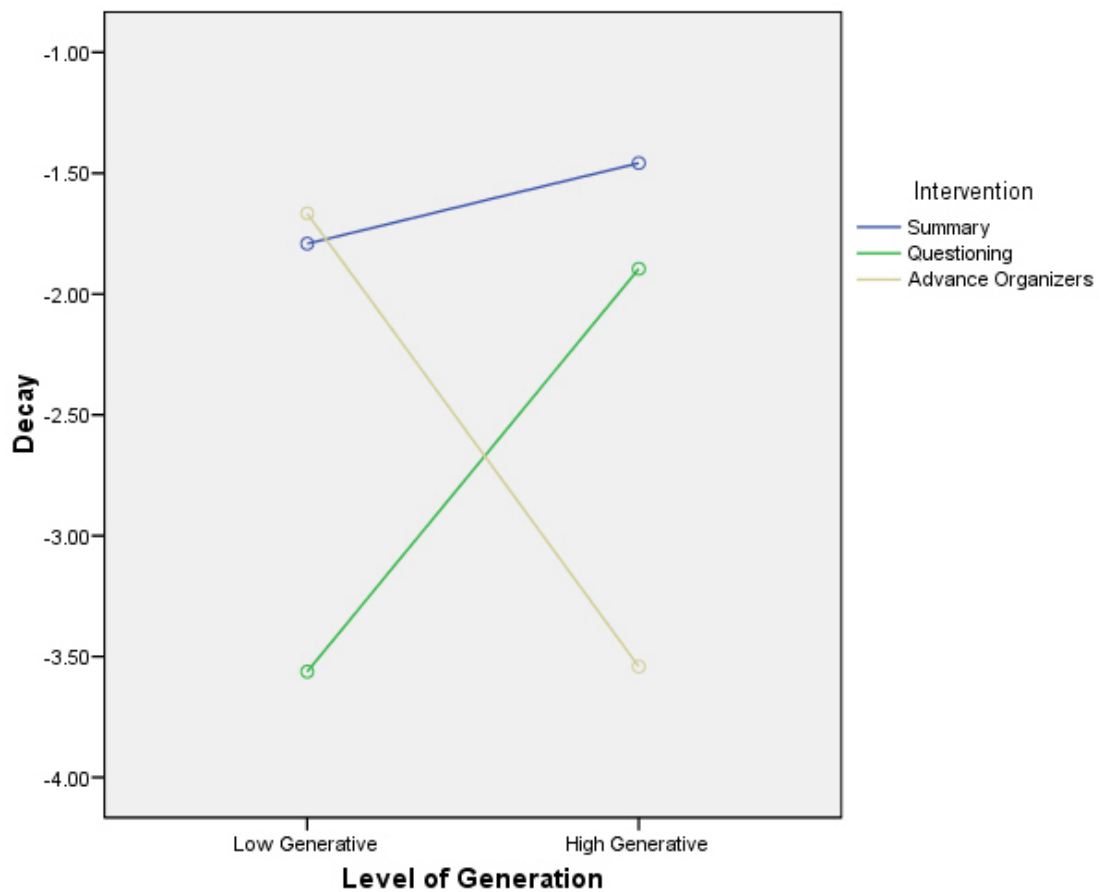


Figure 46. Interaction of Intervention & Level of Generation on Decay

Further analysis was performed to compare the decay between the control group and the interventions. A one-way ANOVA was performed on the difference in test scores between trial 3 and trial 4 (retention trial). The ANOVA results shows no significant difference on retention between the control and the interventions,  $F(3, 80) = 1.319$ ,  $p = 0.274$ , (see Table 29).

Table 29.

ANOVA Results on Retention Score

Source	df	MS	F	Sig.
Intervention	3	8.818	1.319	.274
Within Groups	80	6.687		
Total	83			

Figure 48 shows a graphical display of total test score on trial 3 and trial 4 (retention trial).

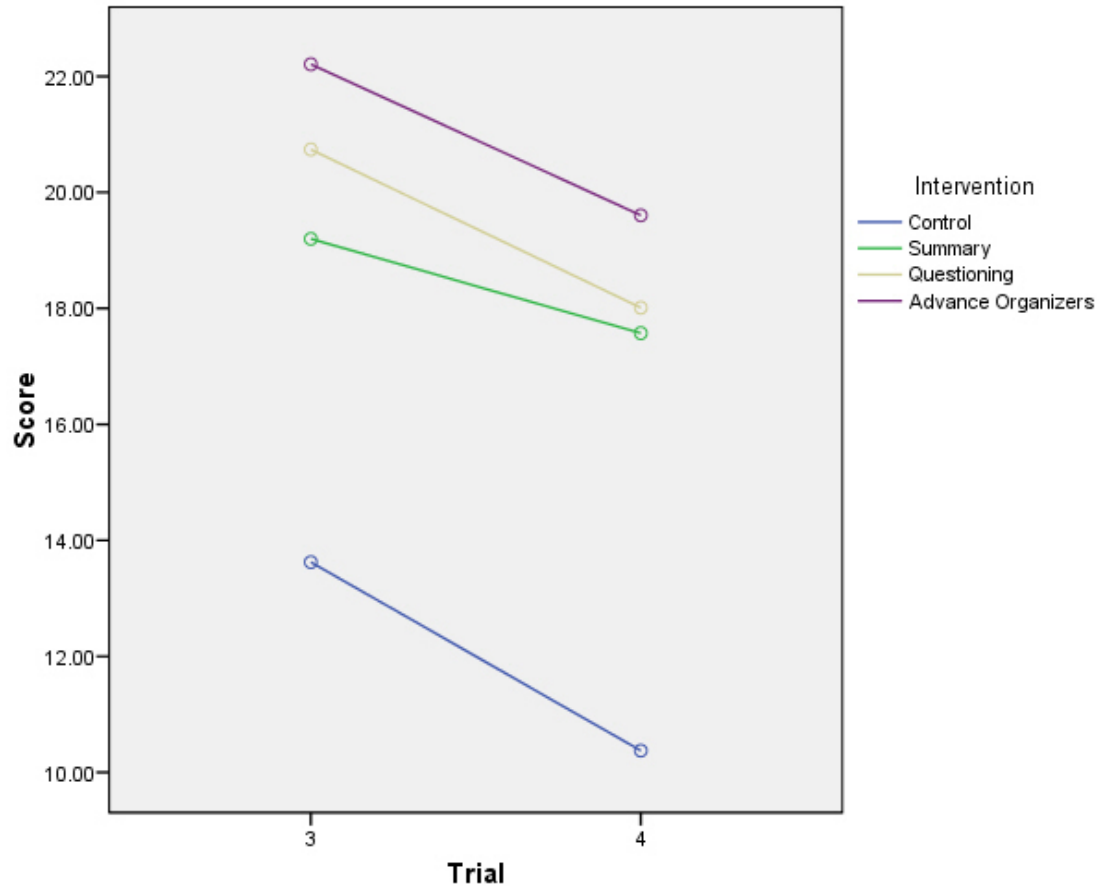


Figure 47. Plot of Score on Test for Trail 3 and the Retention

## CHAPTER 6: DISCUSSION

Based on the theoretical background of this study, two hypotheses were proposed. The first hypothesis was that the integration of knowledge constructions interventions (i.e. summarizing, questioning, and advance organizer), would stimulate the generation of more elaborations leading to better memory for the information to be learned on the part of the student. The second hypothesis proposed that varying the level of self-generation of these elaboration activities would further improve upon the performance of students on a subsequent test of the curriculum material.

The research initially examined the very beneficial learning outcomes of using content free instructional strategies in traditional one-to-one tutoring situations (Chi et al., 2001; Chi et al., 1994; see also Wong et al., 2002; King, 1992a). Though effective, tutoring techniques do not impose any cognitive restrictions nor does it oblige learners' attention to focus on important aspects of the curriculum. The aim of this research was to encourage learners to process information at a deeper level. This notion was motivated by research in the cognitive field namely; schema theory (Anderson, 1994; Rumelhart, 1980; Wong, 1985) and the depth of processing approach ( Craik & Lockhart, 1972). More specifically, prompting participants to generate their own elaborations about the study material is more beneficial to learning as opposed to elaborations presented to them typographically (Anderson & Reder, 1979; Reder, 1979).

The experimental results showed in general, that incorporating the knowledge construction interventions significantly enhanced learning in a computer-based instructional system beyond the mere presentation of the materials. The evidence consistently highlighted the beneficial effect of incorporating the knowledge construction interventions within computer-based instructional systems. It was expected, however, that varying the level of self-generative activity by incorporating the high generative activity within each of the interventions would additionally improve upon students' performance. Conversely, the results did not support this hypothesis, and in some cases, the low generative activity outperformed the high generative activity dependent upon the type of knowledge construction intervention.

The findings will be discussed next in detail starting with a discussion on the interventions, confer on the level of generation effect, and a discussion of the effect of the different treatment combinations employed in this research.

### **The Influence of Interventions**

Incorporating the summarizing, questioning, and advance organizer interventions into the instructional system significantly enhanced post-training test scores as compared to the control group. Participants in the three interventions significantly outscored participants in the control group throughout the three trials. It was interesting to observe that participants in the control group needed three trials to achieve the same score that the experimental groups attained in the first trial. These results showed clearly that

integrating the knowledge construction interventions within the curriculum material had a differential impact on performance as apposed to the mere presentation of the curriculum within the context of a computer-based instructional system.

The interventions were selected, and were thought at an intuitive level, to represent low, medium, and high levels of knowledge construction activities and therefore greater elaboration as per the analysis of Anderson and Reder (1979). In terms of effectiveness, participants using the high constructive advance organizer intervention outperformed participants using the low constructive summary intervention. However, no differences were found between the advance organizer intervention and the questioning intervention or between the summary intervention and the questioning intervention. Hence, varying the level of knowledge construction activities had a mixed effect. These results will be explained in terms of the working memory load following the discussion of specific results relative to the performance measures recorded.

As for study time, there were no differences in the time to study the material between the different treatment combinations and the control group. There were significant differences, however, between the interventions for time needed to elaborate on the materials. Both the questioning and the summary interventions required significantly more time than the advance organizer intervention. This was mainly due to the little time needed by the low generative advance organizer, which was simply provided with a presentation of the organization of the material before the content was provided for study. It should be noted, however, that the high generative interventions (i.e. summary generation, self-generated questioning, and self-generated advance

organizer) required a significantly more time to come up with the elaborations than the low-level interventions (i.e. summary completion, provided questioning, provided advance organizer).

Analysis of the learning gains indicated that most of the learning for the interventions occurred in trial 1 while learning gains for the control group spanned the three trials. Participants in the three interventions were learning the different elements of the curriculum at a much faster rate than the control group. These results could be explained by the fact that participants in the experimental groups are provided with more opportunities to use the knowledge than participants of the control group. This is consistent with Anderson's (1993) ACT-R model of activation of memory structures being a function of opportunities to use the knowledge.

Finally, no differences were found between the different interventions and the control group on retention as measured by the difference between the last post-test and the scores on the retention test. Equivalent rates of decay were found across all experimental and the control group. The scores on the retention test, however, did reflect similar differences in performance between the groups consistent with levels of performance for each group on the third post-test.

### **Effect of the Level of Generation**

The level of generation was designed to solicit two degrees of generative activity on the part of the student. A high degree of generation resulting from having students generate their own elaborations within each intervention and a low degree of generation where students were provided with experimenter created elaborations and relations. There was no significant effect for the level of generation factor. Even though the high generative participants consumed a significant amount of time to produce the elaborations, their test scores were not significantly higher than the scores achieved by participants in the low generative groups. The expectations were based on the notion that the more we engage participants to generate their own connections to the curriculum the greater the number of elaborations would be formed relevant to the student's internal cognitive structure. This in turn would improve upon the relevance of connections formed in terms of relations between concepts and the student's internal state of memory (Chi & Ohlsson, 2005).

The lack of this effect of self-generation in both the questioning and advance organizer groups may be a function of working memory overload. The high generative conditions resulted in the student consuming a large amount of time. Most importantly, the students were obliged to comprehend too many information elements that could have resulted in overloading the executive control and attentional focus of working memory (Cowan, 2005. Consistent with Cowan's (1988 and 1995) Embedded Processes working memory model, working memory is tightly integrated with long-term memory. The processes embedded in working memory consist of a focus of attention subsystem, which



is capacity limited and an active memory which is time limited and is responsible for holding information in working memory which has been activated in long term memory as well as from the focal attention mechanism. In accordance with this model, if focal attention is stressed by task demands as is the case in the generative advance organizer condition, processing working memory becomes overloaded with too many elements which need to be active and too many elements which need to be attended to. This can interfere with encoding of relations. When the task demands are low then the system can focus attention and activate in working memory a number of elements, which can be optimally processed by the student. This would hold true for both the generative advance organizer group as well as the generative question answering group, however, less so for the later as a result of a reduced number of elements which need to be attended to and activated in working memory. In the summary condition, fewer elements are attended to and related due to the nature of the intervention. In this case, however, when the students are required to focus attention on concepts better processing is achieved, resulting in an increase in performance under this condition.

There is a growing body of research, which has shown that as working memory interacting with memory storage, and encoding rises above or below a certain threshold, it will influence performance in a negative way (e.g., Teigen, 1994; Mayer & Moreno, 2003; Niaz & Loggie, 1993; Anderson et al., 1995). According to Pass, Renkl, & Sweller (2004), “it is generally accepted that performance degrades at the memory load extremes of either excessively low load (under-load) or excessively high load (over-load).” The cognitive load theory deals with learning from complex systems where learners “are often

overwhelmed by the number of information elements and their interactions that need to be processed simultaneously before meaningful learning can commence” (Sweller, 1988, 1999).

Although cognitive load theory does not discuss mechanisms, as does Cowan’s Embedded Processes model, it does distinguish between three categories of cognitive loads. The first category is called intrinsic cognitive load, which is concerned with element interactivity of the material being learned. Element interactivity is a characteristic of complexity of the curriculum and obviously cannot be altered unless by omitting some elements to reduce this kind of load. The second category is called extraneous or ineffective cognitive load, such as instructional procedures that requires learners to perform activities that will overload working memory, i.e. when part A of an explanation refers to part B without indicating clearly where part B is to be found ( Pass, Renkel, Sweller, 2003). The third category of cognitive load is called germane or effective load, which deals with the load that the learning intervention requires of learners to enhance learning and understanding of the materials. This would be the type of load characteristic of the interventions examined in this study.

Two categories of the cognitive load theory appear to be relevant to this study. The curriculum (intrinsic cognitive load) used in this study was complex and required participants to learn many information elements and concepts simultaneously. The complex learning experience was coupled by adding the knowledge construction interventions (germane or effective load).

The findings of this research confirm the cognitive load theory at the excessively high load edge. For example, participants requested to generate their own organization of the material, the high end of knowledge construction interventions, failed to achieve the best performance over other low generative prompts experimented with in this study. The effective load here seems to be excessive. Participants needed to go back and fourth through the curriculum to produce their organization of the curriculum and to examine the material in order to formulate questions as well as answers about the concepts indicated. This load was in addition to the cognitive load required to learn the different elements of the curriculum and most probably overloaded their working memory. This was evident by the time needed to elaborate on the material. For instance, it was interesting to observe that in trial 1, the generated advance organizer participants needed 29 minutes to achieve their score compared to only 3.3 minutes for the provided advance organizers participants. In trial 2 and trial 3, however, participants in the high generative interventions simply repeated their efforts on the first trial. Hence, differences in elaboration times between the high and low generative interventions were diminutive.

Cuevas (2004) when training participants to learn principals of flight obtained similar results. She used high-level elaboration queries to prompt participants to generate a sentence that connected three or more concepts from a list that best described the relation among those concepts (complex sentence) as compared to simple low-level elaboration queries that prompted participants to generate a sentence using only one of the terms from this list (simple sentence). The lists contained eight or more concepts and covered several lessons in the principles of flight curriculum. The high-level elaboration

queries failed to produce significantly better post-training outcomes than the no-query or the low-level elaboration query training conditions. Apparently, participants had to go back through several lessons to search for these concepts and generate the sentence. This could by far overload their working memory and as a result, hindered the post-training test score.

Within the context of this work, the generative activity will not produce better results by simply engaging the learners to produce more elaborations, by employing the high generative prompts. However, at the low level of knowledge construction where students were required to generate sentences employing two or three concepts covered in the immediately preceding content, the high generative activity did produce improved performance. It can be inferred, that this condition did not overload working memory and the encoding of memory structures, producing the intended effect. Whatever the explanation for the effects found herein, it seems that adequate measures should be employed to balance the cognitive load and the generative activity imposed on learners to achieve optimum learning outcomes.

Lastly, there was a significant difference between the low and high level of generation in terms of time needed to produce the elaborations. The high generative prompts required a significantly more time to come up with the elaborations than the low-level prompts. Certainly, this was expected due to the demanding nature of the high generative prompts.

### **Affect of the Treatment Combinations**

Next, we will present how participants performed in each of the treatment combination. The discussion will highlight the matrix of performance on tests, time on elaboration, and the cognitive load imposed on participants for each of the prompts.

More than expected, participants in the provided advance organizer group outperformed the summary completion and the generated questioning groups. By definition, advance organizers provide anchors to earlier experiences and knowledge; it also directs attention to upcoming materials (see Ausubel, 1963). Considering the complex nature of the curriculum, novice participants would have made no, or at the most minimum, anchors and connections since the information contained in the curriculum is very new and unique. Hence, the enhanced learning, in terms of post training test scores, is a product of directing learners' attention to the important aspects of the curriculum and this conceivably provided participants with a point of reference to what to look for while reading the curriculum. Obviously, the provided advance organizer had a low cognitive load and most likely had a positive impact in the encoding of the correct relations between the different elements of the curriculum. The provided advance organizer was very efficient to use, learners needed the least time to elaborate, 3.38 minutes for trial 1 (2.2 minutes on the average, across all trials).

There was no significant difference between the high generative, generated advance organizer group, and the rest of the treatment combinations. As mentioned previously, the generated advance organizer was designed in such a way that necessitated participants to provide their organization of the curriculum with the help of a list that

contained all the components and functions of the M1A2 data bus. Participants had to go back and fourth through the curriculum to produce their organization of the material. They needed the most time, 28.8 minutes for trial 1 (15.8 minutes on the average, across all trials), to produce their elaboration. Evidently, the activity was difficult enough to overload the working memory limited capacity and resulted in less than desired performance as discussed previously.

The generated questioning activity had a similar effect of the generated advance organizer in overloading working memory. Subjects were asked to generate questions and then provide answers to their own questions using the provided keywords from the curriculum. The activity may have been too demanding in terms of time and information elements required to generate the elaborations. This activity probably overloaded participants' active memory (time limited capacity) trying to hold the information elements for too long in an attempt to generate the elaborations. There were no significant differences in post-test scores between the generated questioning group and the rest of the treatment combinations. In fact, the generated questioning group scored significantly less in posttests than the provided advance organizer group. The time required to elaborate was considerable, 21.53 minutes for trial 1 (15.7 minutes on the average, across all trials).

The provided questioning group differed from the generated questioning group in that the questions were provided by the instructional system. The system provided questioning group performance was not significantly different from other treatment combinations. The time required to produce the elaborations was 17.25 minutes for trial 1

(13.35 minutes on the average, across all trials).

Although the summary generation activity was categorized in the low side of the generative interventions, the summary generation group performed as well as other high generative prompts. The activity of generating sentences using key words from the curriculum was intuitive and very natural for the participants and appeared to be successful in creating better learning afterward. It seems that this activity did not overload working memory and the encoding of memory structures, producing the intended effect. Participants in the summary generation group required, 24.47 minutes in trial 1 (19.05 minutes on the average, across all trials) to produce the elaborations.

The summary completion activity required participants to place missing words in sentences, which were straightforwardly available in the slide text, and has very low cognitive load. Even with this simple activity, the summary completion group outscored the control group in the posttests and performed as well as other high generative activities except the provided advance organizer. The time required to elaborate was 18.73 minutes for trial 1 (14.23 minutes on the average, across all trials).

## **Implementing the Knowledge Construction Interventions**

In general, incorporating the knowledge construction interventions into the computer-based instructional system was readily an easy task, which required a slight additional effort in terms of time and programming. Specific implementation issues for each intervention are discussed next.

Though creating the provided advance organizer required effort and good grasp of the curriculum, implementing the advance organizer on the other hand, was effortless. The task was inserting a page long text in the beginning of the curriculum and there was no need to alter the main body of the training materials. Incorporating the provided advance organizer into the computer-based instructional system had an enormous 269% improvement in the test score on trial 1 (198% across all trials) as compared to the control group.

Generating the list of key concepts and components for the generated advance organizer intervention was an easier task than creating the advance organizer for the provided group. Implementing the generated advance organizer, on the other hand, was identically similar to the provided advance organizer by inserting a page long text at the end of the curriculum and there was no need to alter the main body of the training materials. The webct facilitated the capturing of the elaboration by taking advantage of the system's built-in text editor. Incorporating the generated questioning intervention into the computer-based instructional system had a 235% improvement in the posttest score on trial 1 (168% across all trials) as compared to the control group.



Implementing the generated questioning intervention required more effort than implementing the advance organizer interventions since it was necessary to place the prompts within various points of the curriculum. The system asked participants to type-in questions and provide answers to their own questions. As in the generated advance organizer, the elaborations were collected using the webct's built-in text editor. Incorporating the generated advance organizer into the computer-based instructional system had a 184% improvement in the test score on trial 1 (152% across all trials) as compared to the control group.

The provided questioning intervention was implemented exactly as the generated questioning intervention. The only difference was that the provided questioning prompts asked participants to type-in answers to the system provided questions. Incorporating the provided questioning intervention into the computer-based instructional system had a 228% improvement in the test score on trial 1 (172% across all trials) as compared to the control group.

The implementation of the summary completion intervention required similar effort to that of the questioning prompts since participants were provided with sentences and asked to fill-in missing words. The prompts were inserted exactly at the same location in the curriculum as the questioning prompts. Incorporating the summary completion intervention into the computer-based instructional system had a 183% improvement in the test score on trial 1 (145% across all trials) as compared to the control group.

Lastly, the summary generation intervention required the same effort of implementing the summary completion intervention. Participants were provided with keywords from the proceeding material and asked to type-in their generated sentences. Incorporating the summary generation intervention into the computer-based instructional system had a 236% improvement in the test score on trial 1 (169% across all trials) as compared to the control group.

## CHAPTER 7: CONCLUSIONS

The present research investigated the effectiveness of incorporating knowledge construction interventions within the context of computer based information systems. A significant portion of this work was the theoretical development to justify the integration of knowledge construction interventions within computer-based information systems. Synthesis of various theories from many fields was necessary to pave the path for this work.

The research initially examined the very beneficial learning outcomes of using content free instructional strategies in traditional one-to-one tutoring situations (Chi et al., 2001; Chi et al., 1994; see also Wong et al., 2002; King, 1992a). Though effective, tutoring techniques do not impose any cognitive restrictions nor directs learners' attention to important aspects of the curriculum. The aim of this research was to encourage learners to process information at a deep level. This notion was motivated by research in the cognitive field namely; schema theory (Anderson, 1994; Rumelhart, 1980; Wong, 1985) and the depth of processing approach ( Craik and Lockhart, 1972).

The knowledge construction interventions were a collection of well-known learning strategies that have been used in traditional classroom settings and demonstrated to have a positive impact on learning. This research endeavor pioneered to incorporate these interventions into computer based systems information systems. These interventions were designed to guide the cognitive processes of learners as opposed to the

open-ended strategies found in previous research. Particularly, the interventions were intended to scaffold learners' cognitive processes, activate appropriate prior schema about the curriculum under study, and ultimately promote participants to process the material at a deeper level. The evidence consistently highlighted the beneficial effect of incorporating the knowledge construction interventions within computer-based information systems.

In sum, this study provided strong evidence that the integration of knowledge construction prompts activities within the curriculum material have improved understanding of the curriculum content and reasoning about such content over and above the mere presentation and study of the curriculum. The research also delineated a practical way on how to incorporate and operationalize the knowledge construction interventions within computer-based systems information systems. These interventions were only used in traditional classroom setting previously.

Recommendations for future research in this area are as follows:

1. Examine the utility of the rest of the generative prompts identified in this research.
2. Consider the motivational factors of participants and their effect on the overall utility of the knowledge construction interventions.
3. Fine-tune these prompts as when, where, and how many to use in a particular setting.

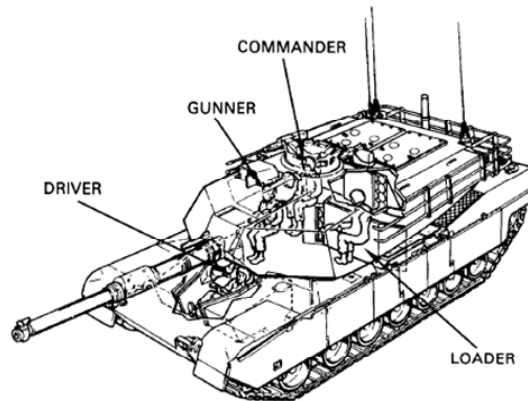
4. Compare the content-free prompts to the knowledge construction interventions.
5. Balance the cognitive load and the generative activity imposed on learners to achieve optimum learning outcomes.

## **APPENDIX A: THE CURRICULUM**

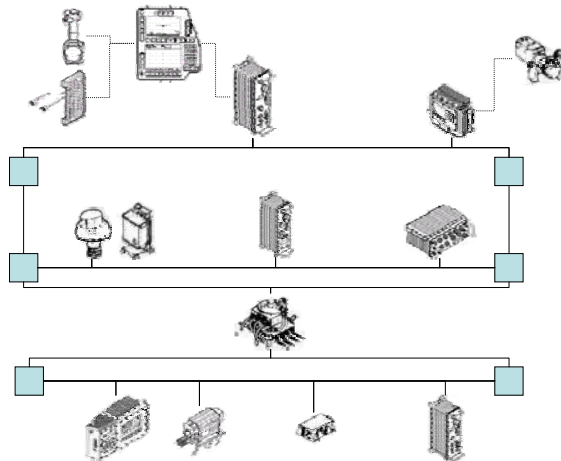
## M1A2 Tank Overview

### Objective: Familiarization with the M1A2 Tank

The M1A2 SEP combat tank uses high speed, maneuverability, and a variety of weapons to accomplish its mission. The tank provides protection from enemy weapons. It has a crew of four individuals. The driver is located in the hull the Gunner, Commander and Loader are Located in the Turret. This training will focus on the 1553B it is the data communications component of the M1A1SEP



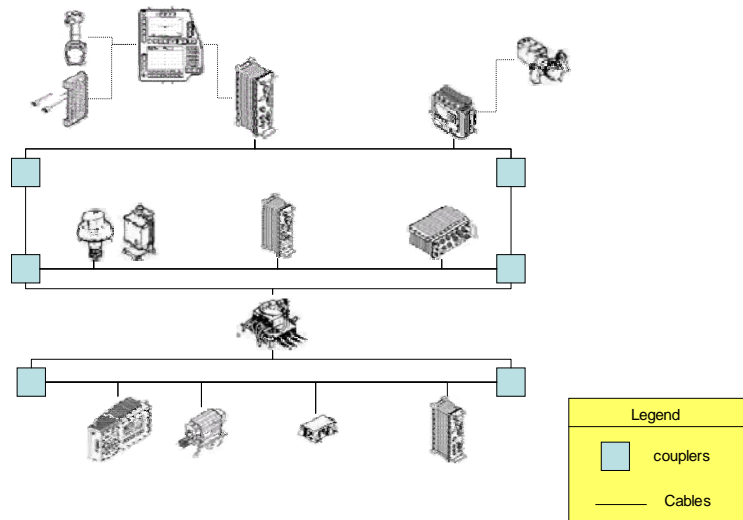
## M1A2 Tank Function



The M1A2 SEP tank system architecture is a set of distributed tank components interconnected to each other by a power distribution network and data distribution network(1553B Bus). This training will only address the 1553 Bus Data Distribution Network.

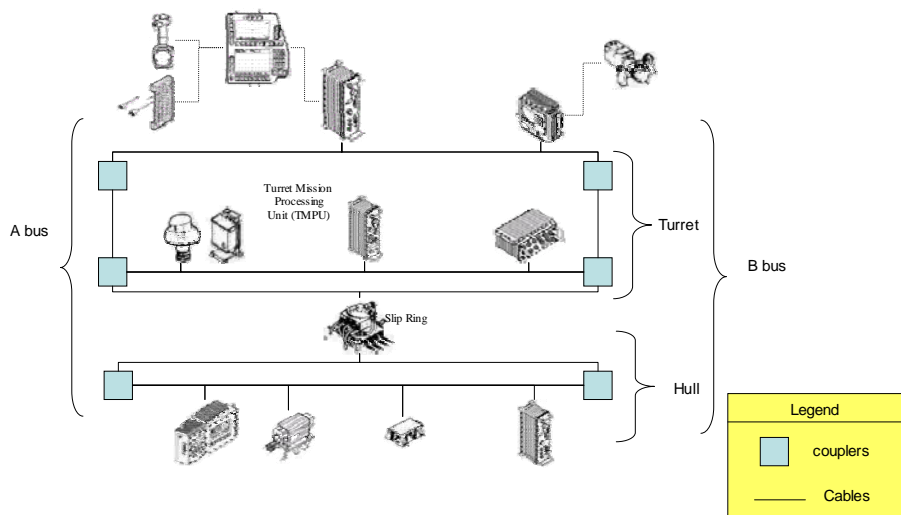
### 1553 Bus Function

Function: The 1553B Data Bus communicates all data messages to *control* and *monitor the functions and applications* of the tank. The diagram has all of the components of the 1553 Data Bus along with the wires and couplers that make up the data bus.



### 1553 Bus Mechanism

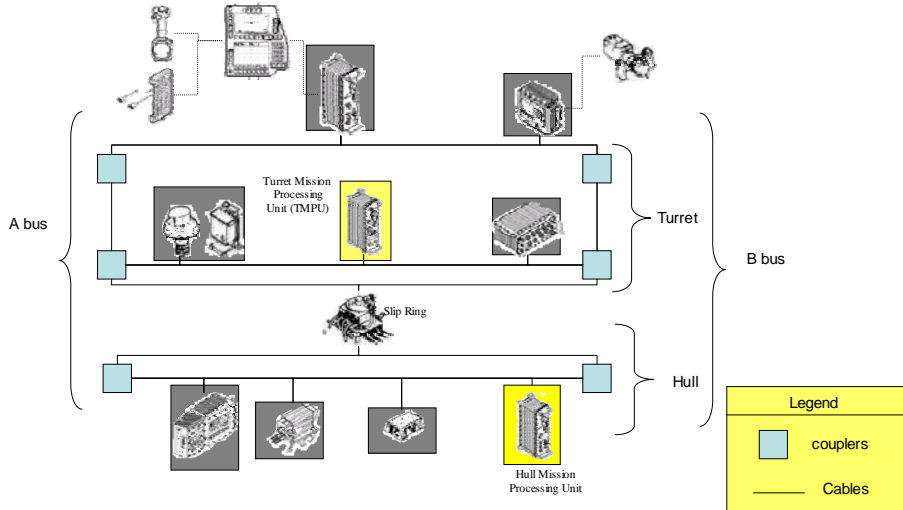
Mechanism: The 1553b data bus consist of a bus controller (also known as the Turret Mission Processor Unit) that *transmits* and *receives messages* across cables, through the slip ring and couplers. The controller communicates to a monitor and other remote terminals on this bus. This 1553b data bus is *dual redundant* with both an A bus and a B bus. It serves both turret functions and some hull functions.





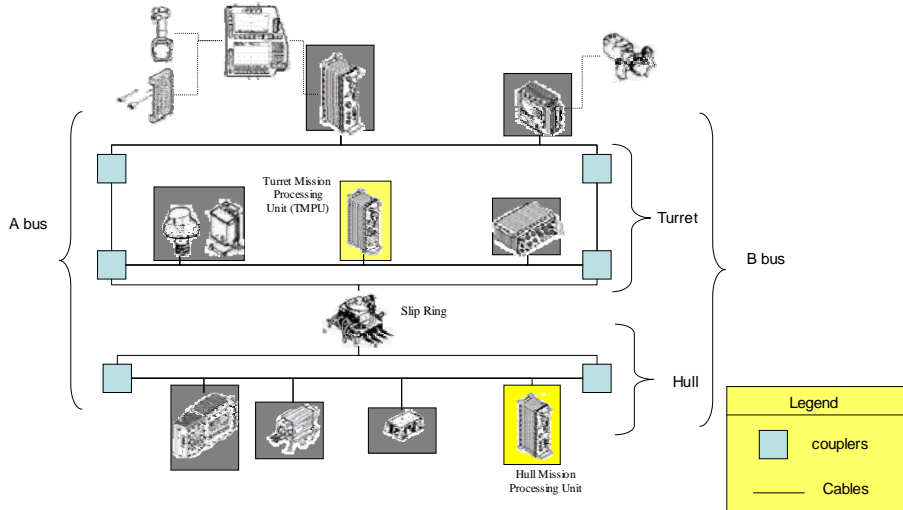
Function: The A and the B buses insure dual redundancy in the system. They distribute messages to all of *Remote Terminals* and the *Bus Monitor/Hull Mission Processing Unit (HMPU)* from and to the *Turret Mission Processing Unit (TMPU)*. If any bus is damaged the other bus, either the A or B bus which is not damaged, can still transmit information between the *Remote Terminals* and the *Turret Mission Processing Unit (TMPU)*.

Mechanism: The A bus and B bus consist of a series of cables and couplers that connect the *Bus Controller*, *Bus Monitor* and *Remote Terminals*.

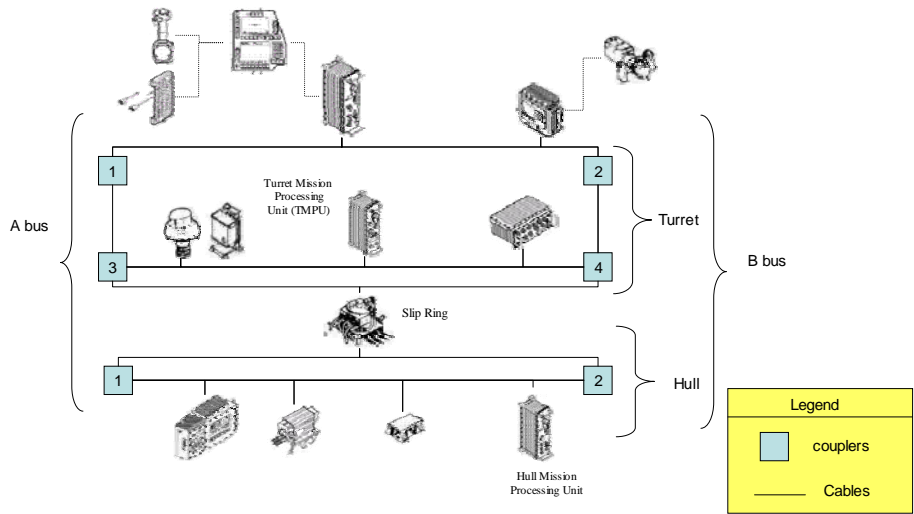


The A and B bus couplers distribute data and messages by bus cables to different Remote Terminals. They connect the *Bus Controller (Turret Mission Processing Unit TMPU)* and *Bus Monitor (Hull Mission Processing Unit HMPU)* to different Remote Terminals.

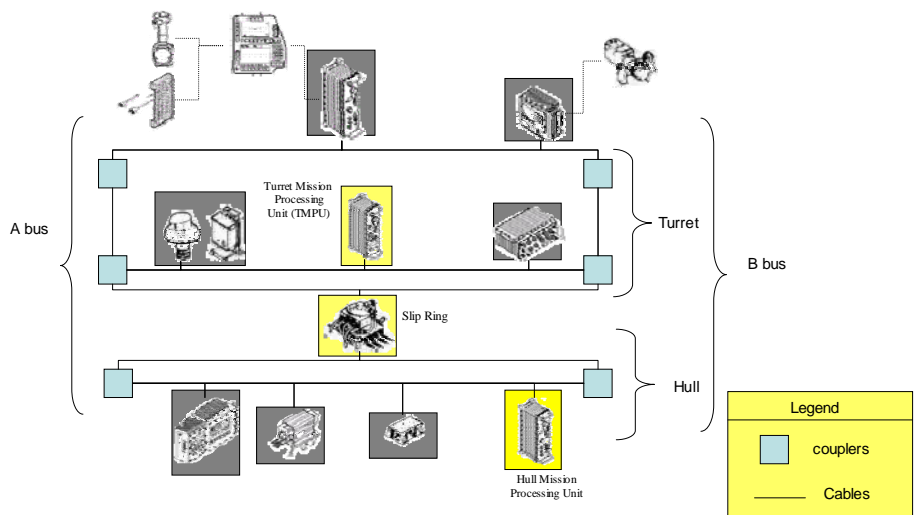
Bus Couplers isolate the A and B Bus to ensure that failure of one of the *Remote Terminal Units*, the *Turret Mission Processing Unit (TMPU)* or the *Hull Mission Processing Unit (HMPU)* will not result in main bus failure. They ACT AS A SURGE Protector protecting other components.



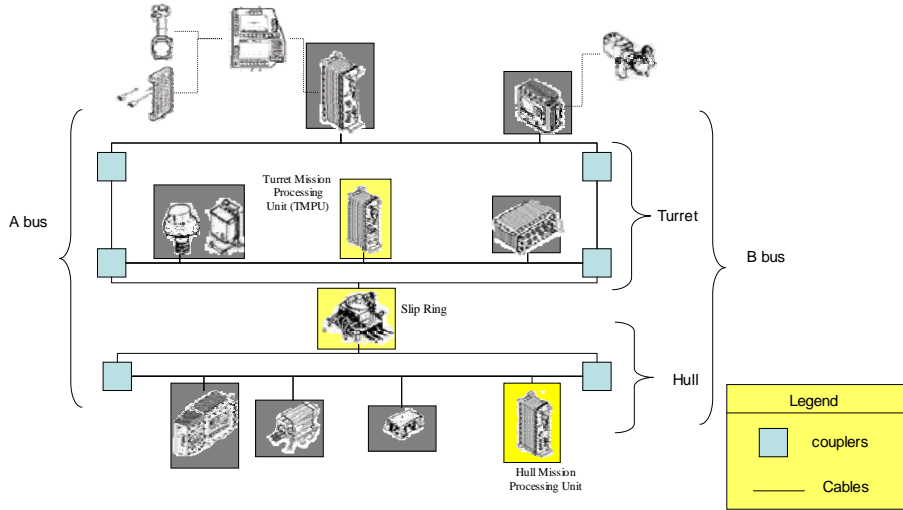
Four bus couplers are located in the *turret* and two are located in the *hull* in different locations. They are connected via cables and the slip ring. The couplers connected by cables routed along different paths to provide redundant capability.



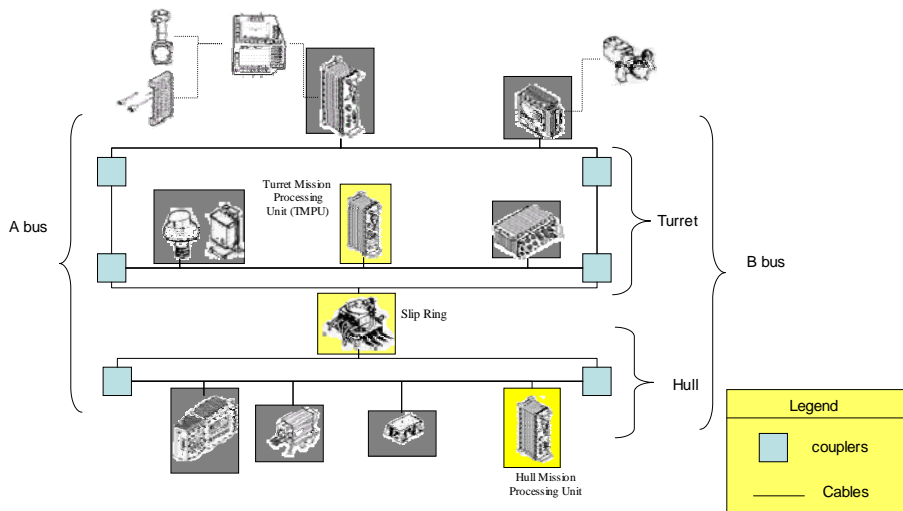
Function: The bus cables are the communication lines between the components of the bus system. They carry all information between components.



Mechanism: *Data bus cables* are a twisted pair of wires, which are shielded and connected to the *Turret Mission Processing Unit (TMPU)*, the *Hull Mission Processing Unit (HMPU)* and other *Remote Terminals*. The cables connect the *TMPU* and the *HMPU* and *Remote Terminals* to the *A bus couplers* and *B bus couplers*. Cables connect to the slip ring so the connection from the *turret* to the *hull* can be made. The cables are routed on different sides of the vehicle to provide redundant capability

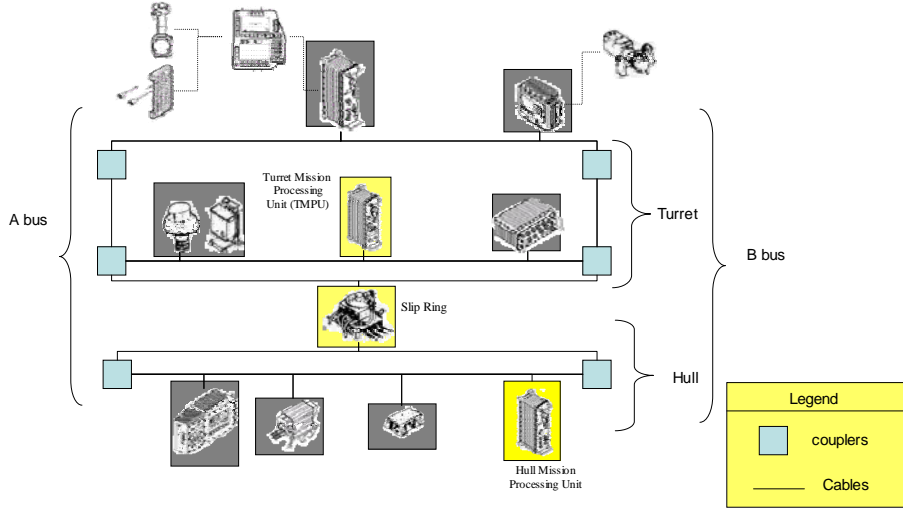


Function: The *Slip Ring* forms the communications link between the two A bus couplers and two B bus couplers which serve the Turret and one A bus coupler and one B bus coupler which serve the Hull.

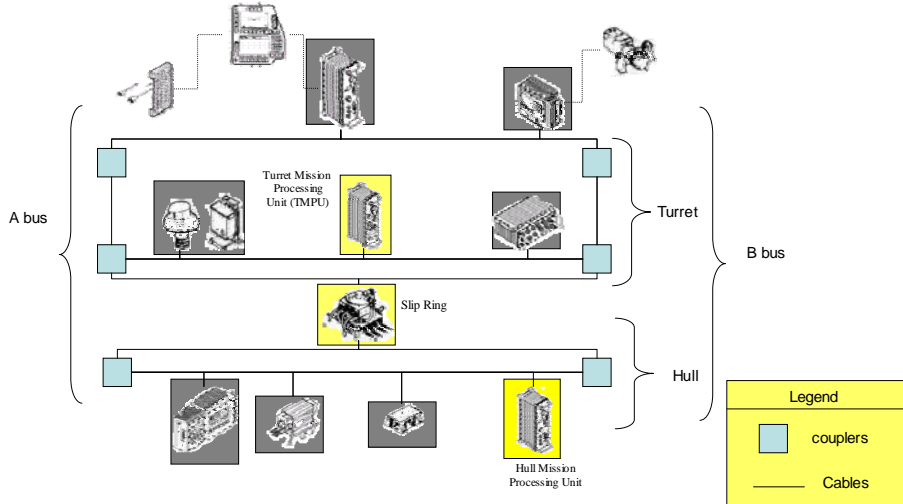


Function: The bus controller is referred to as the *Turret Mission Processing Unit (TMPU)*. It sends and controls the flow of messages across cables through couplers and their cables to remote terminals.

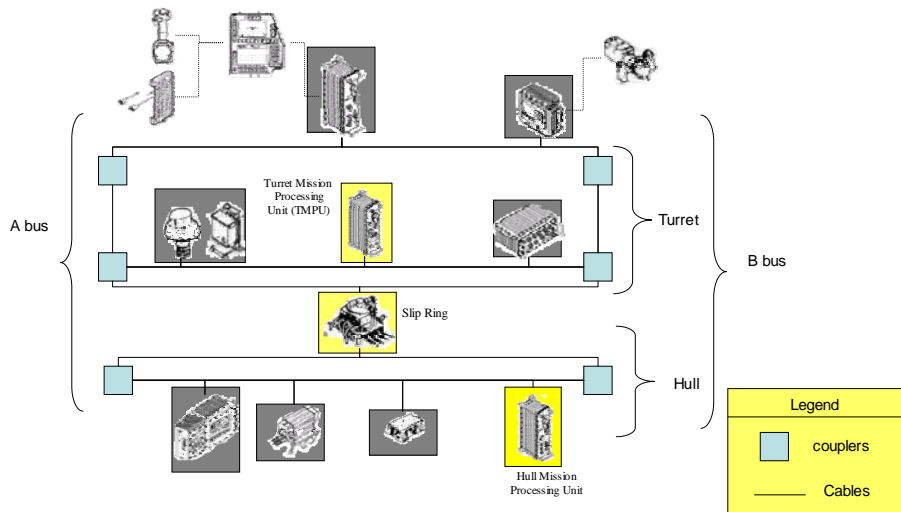
The *TMPU* is also responsible for conducting all system diagnostic checks and for calculating ballistic solutions for the tank under normal operations. These diagnostic and ballistic functions make the *TMPU* like another remote terminal.



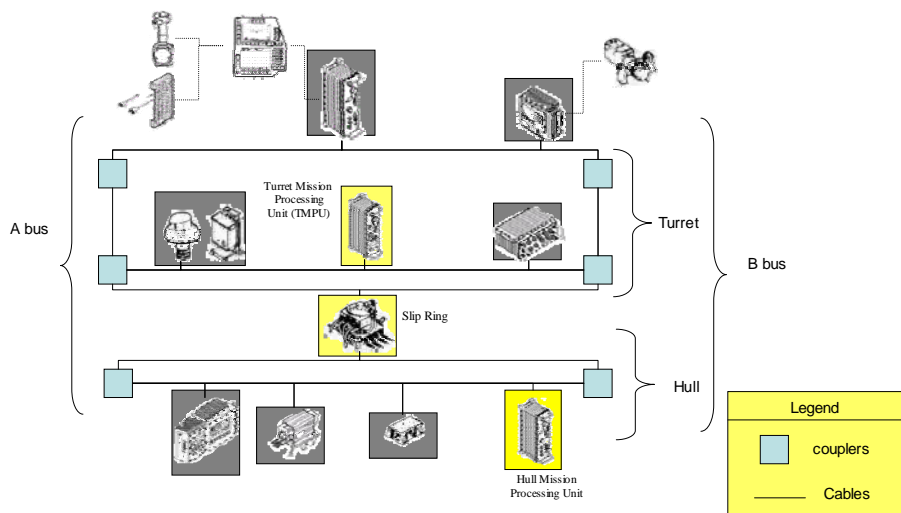
Mechanism: The *TMPU* communicates to *Remote Terminals* through redundant A and B buses. The *TMPU* consists of many computer processors which *control and manage* information transmission throughout the tank Turret systems and the Hull systems by way of cables and couplers. The *TMPU* talks to the *Bus Monitor* referred to as the *Hull Mission Processing Unit (HMPU)* through the A bus and B bus via the slip ring. The *TMPU* by way of the A and B buses can talk to all Remote Terminals, which perform various functions. The *TMPU* can control the talk between any two *Remote Terminals* by way of the A and B buses. Only one terminal can talk to one terminal at a time and the sequence in which any two terminals can talk is established by a fixed priority by the bus controller.



In addition to the *communication and control functions* of the *TMPU*, it also carries out *special functions like other Remote Terminals*. As with other remote terminals it receives and transmits data on the bus in response to bus controller commands. As a *remote terminal it calculates ballistic solutions for the fire control systems and performs system diagnostics*.

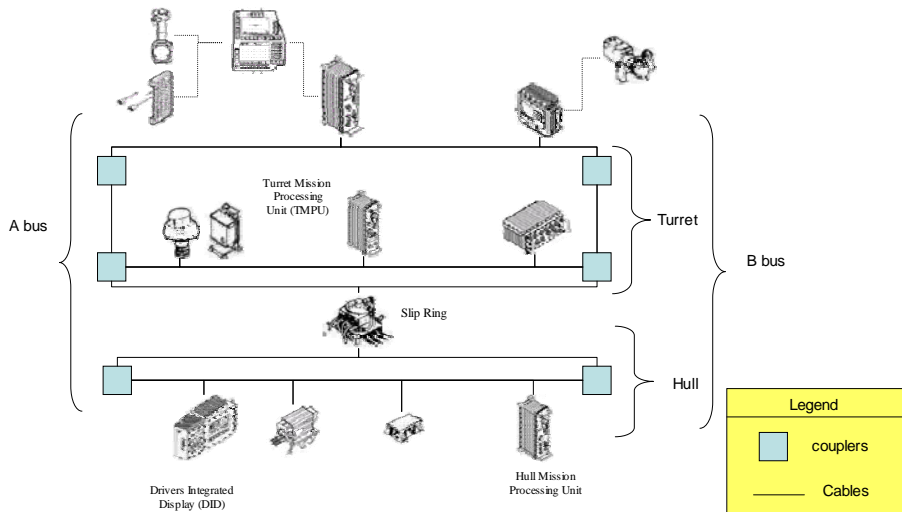


One of the *TMPU's* Remote Terminal functions is calculating ballistic solutions for the Fire Control System. It does this by storing and managing *critical data* such as Boresight data, plumb and sync., scan limits and rate, all drift data, ammo type, all zero data, Commander's Independent Thermal Viewer adjustments, and Sensor inputs for crosswind, cant, lead, ammo temperature and battle-sight range which is then used to *compute solutions for the fire control system employing the processors and the software of the TMPU*.



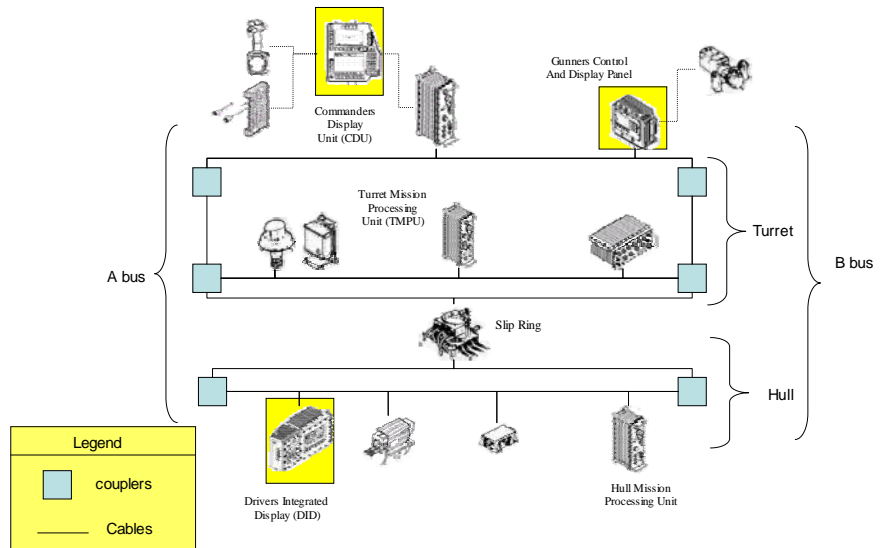
15 Remote Terminal Function of the Turret Mission Processing Unit: Diagnostic Group 1

Another Remote Terminal-like function of the Turret Mission Processing Unit (TMPU) is *diagnosing system components*. There are three different types of test, the *Self-Test (ST)*, the *Built in Test (BIT)* and the *Fault Isolation Test (FIT)*.



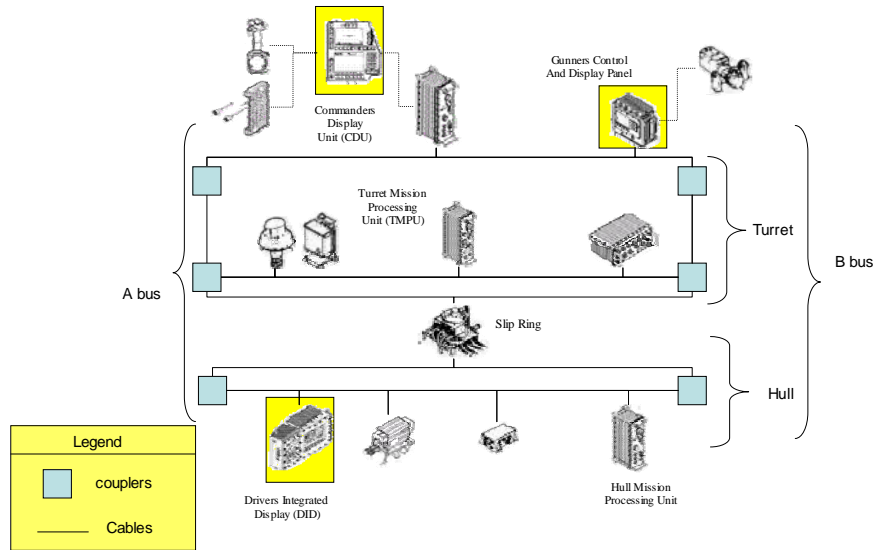
16 Remote Terminal Mechanism of the Turret Mission Processing Unit: Self Test Group 1

*Self-Test* is designed to run in the background without interfering with normal operations. If a fault is detected by the *Self-Test*, a caution or warning message is displayed in one of three locations; the *Commander's Display Unit*, the *Gunner's Control Display Panel* or the *Driver's Integrated Display*. This is an automatic test and runs constantly in the background.



17 Remote Terminal Mechanism of the Turret Mission Processing Unit: Built In Test Group 1

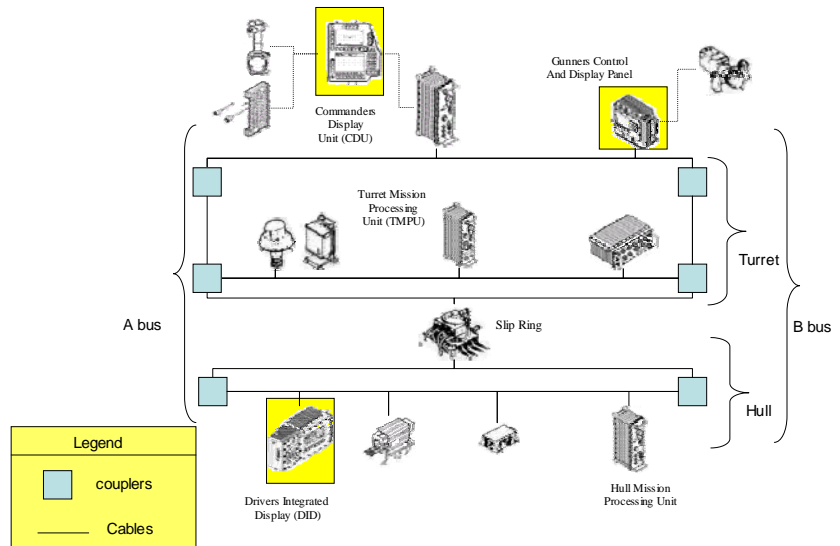
The *Built in Test* is designed to provide extensive and comprehensive test coverage of the component in which the *BIT* is embedded. The *BIT* is an intrusive test which requires components to be shut down. When a fault is detected by *BIT* in its related component, it will display a NOGO message on the *Commander's Display Unit*, the *Gunner's Control Display Panel* or the *Driver's Integrated Display* to alert the crew or mechanic that a fault has occurred



18 Remote Terminal Mechanism of the Turret Mission Processing Unit: Fault Isolation Test Group 1

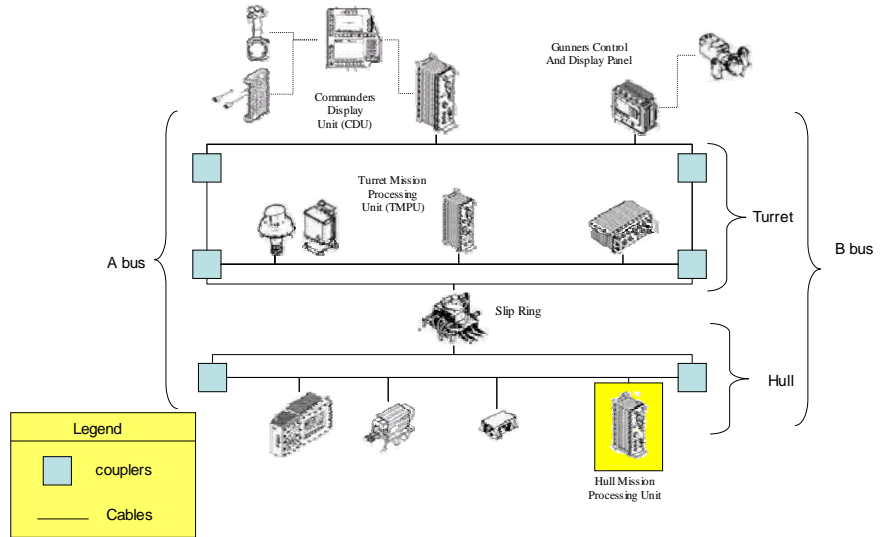
Fault Isolation Test

The *Fault Isolation Test (FIT)* is designed to pinpoint a fault within a group of detected failures or support further testing of the system beyond the capabilities of the *Self-Test* or the *Built-In test*. Maintenance personnel will conduct *FIT* from the *Commander's Display Unit*, the *Gunner's Control Display Panel* or the *Driver's Integrated Display* depending upon the type of fault detected.



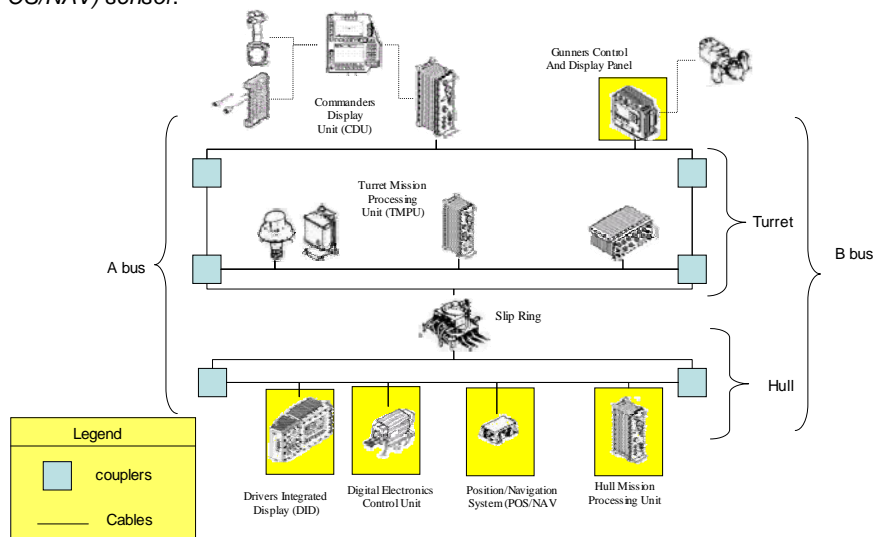
### Bus Monitor/HMPU Function

Function: The *Bus Monitor* or the *Hull Mission Processing Unit (HMPU)* is the *backup* for the *Bus Controller* or *Turret Mission Processing Unit (TMPU)*. If the *TMPU* fails, the *HMPU* can carry out all of the *Bus Controller* functions *except for the use of Global Positioning System information*. Global Positioning System information used for position information is fed directly to the *TMPU* and cannot be accessed by the *HMPU*. *This is the only function which is not dual redundant in the 1553B bus system*. The *HMPU*, like the *TMPU* can send messages across cables through couplers and their cables to remote terminals in the Hull and through cables, couplers and the slip ring to the remote terminals in the turret.



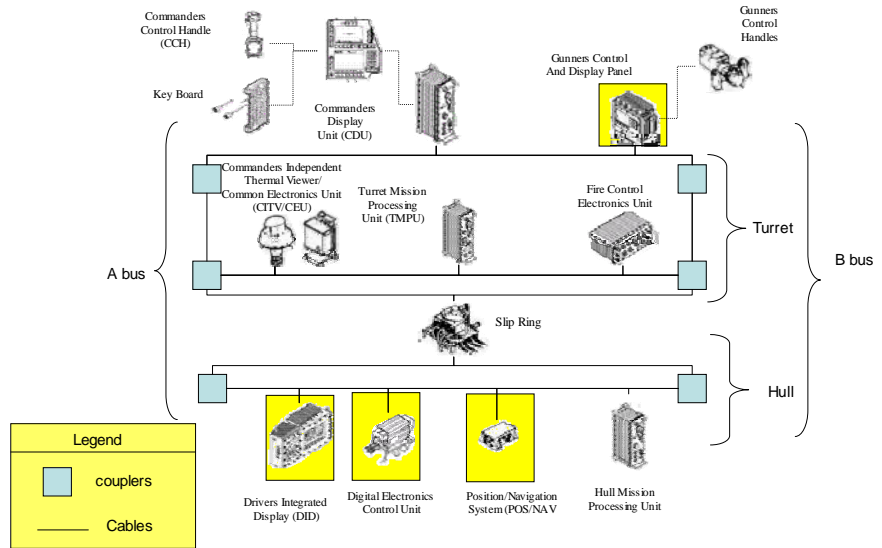
### Bus Monitor/HMPU Mechanism

Mechanism: The *Hull Mission Processing Unit (HMPU)* is also connected to two couplers one on the A bus and one on the B bus in the same way as the *Turret Mission Processing Unit (TMPU)*. This makes up six couplers in all with the addition of the two A and two B bus couplers of the Turret system. Three on the A bus and three on the B bus. The other Remote terminals which are connected along with the HMPU to these two couplers are: The *Driver's Integrated Display Unit (DID)*, the *Digital Electronics Control Unit (DECU)* and the *Position Navigation (POS/NAV) sensor*.



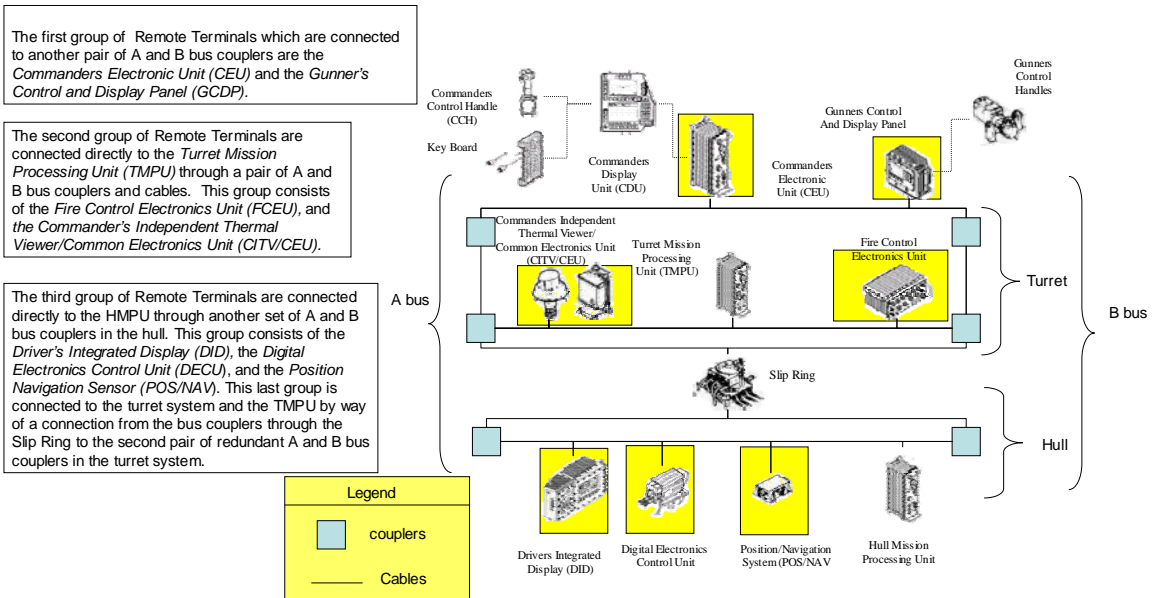


The *Remote Terminals* receive and transmit data on the bus in response to bus controller commands. They are connected to the A and B bus couplers in a specific way, such that, different Remote Terminals are connected to different A and B bus couplers. The couplers in turn are connected to each other on the A and B buses to route all information to the *TMPU* and the *HMPU*.



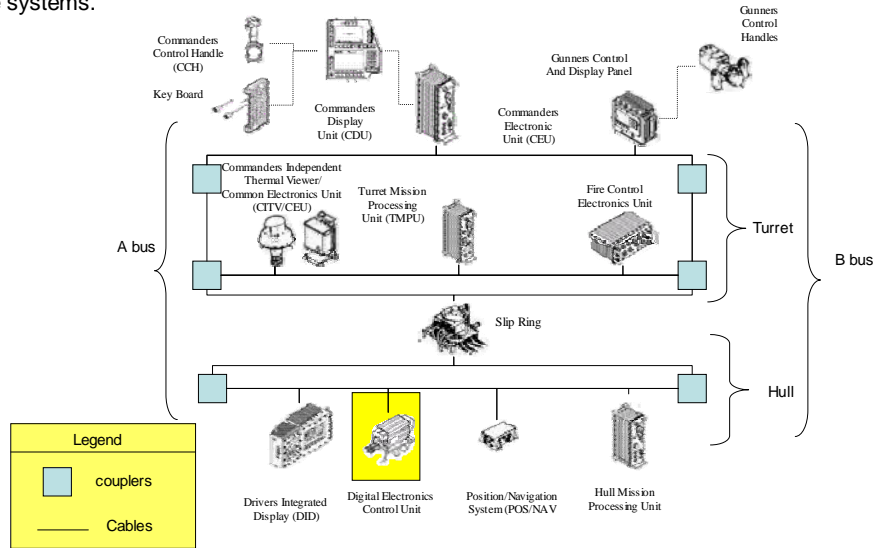
Mechanism of the Remote Terminals: The Remote Terminals are separated into three groups.

Each group of Remote Terminals is connected to a pair of A and B bus couplers.



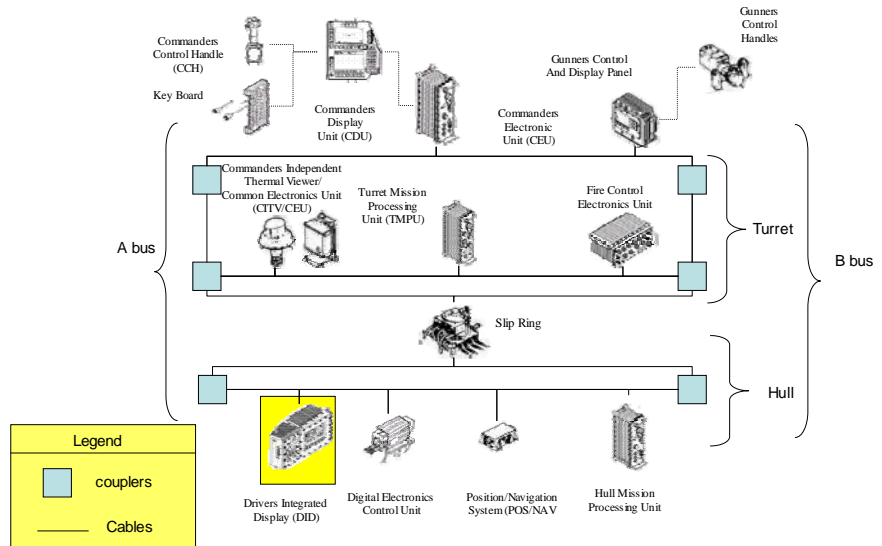
. The Function of the Digital Electronics Control Unit (DECU):

The function of the *Digital Electronics Control Unit (DECU)* is to control certain displays within the *Driver's Integrated Display* through the 1533B bus. The DECU converts analog to digital signals and provides control and monitoring of engine systems.



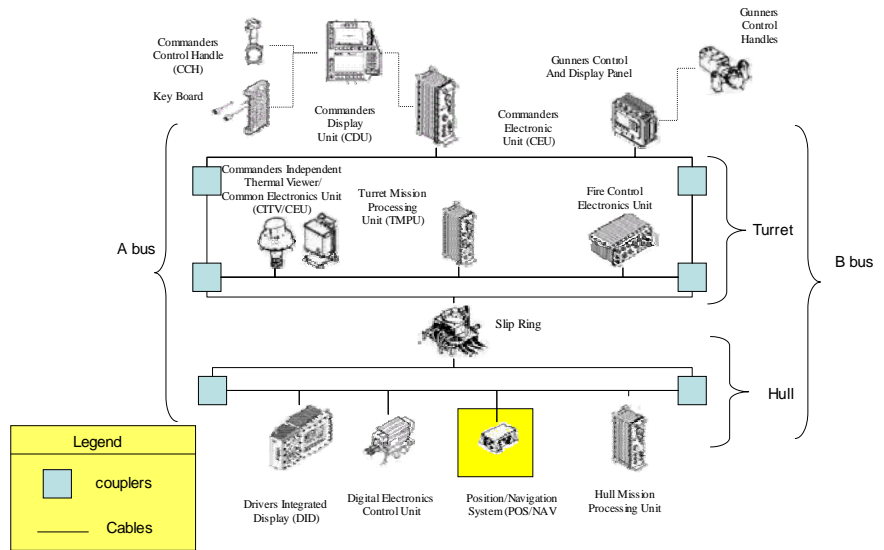
The Function of the *Driver's Integrated Display (DID)*:

The function of the *DID* is to allow the driver access to all automotive related functions and to select back-up functions of the commander's display unit



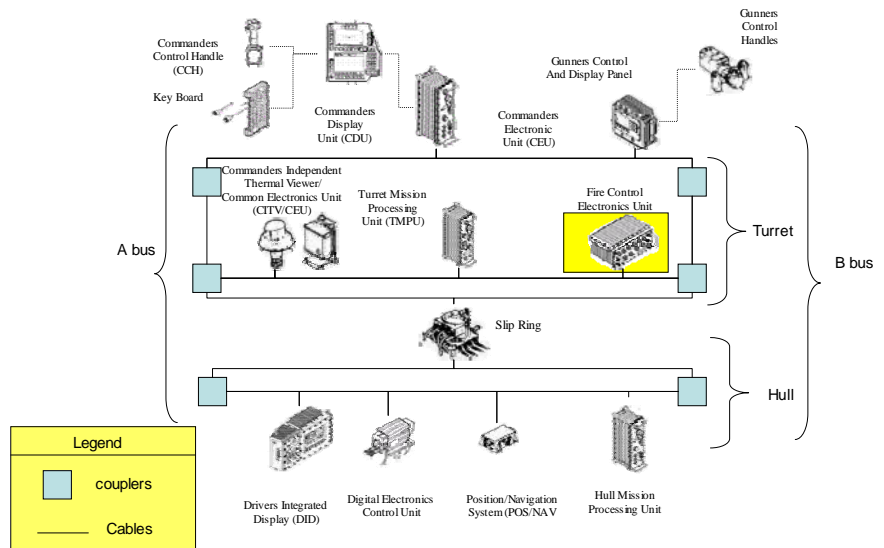
### Remote Terminal Position Navigation Sensor (POS/NAV)

The function of the *Position Navigation Sensor (POS/NAV)* is to provide movement and direction data for the commander, driver and the fire control system. It also provides *dynamic cant for the Fire Control System*.



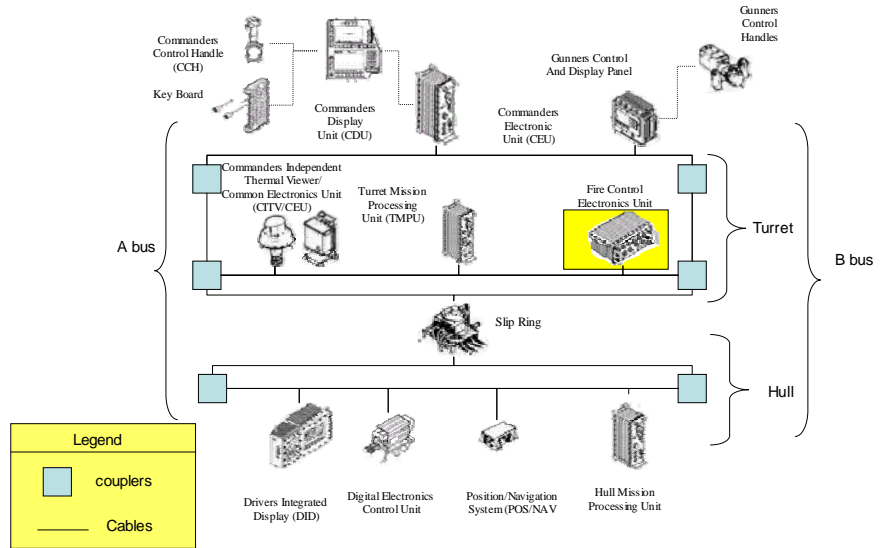
### Remote Terminal Fire Control Electronics Unit (FCEU)

The function of the *Fire Control Electronics Unit (FCEU)* is to integrate the Gunner's Primary Sight with the *Commander's Independent Thermal Viewer*. This allows the Commander to engage a target from the CITV or from the Gunners Primary Sight.



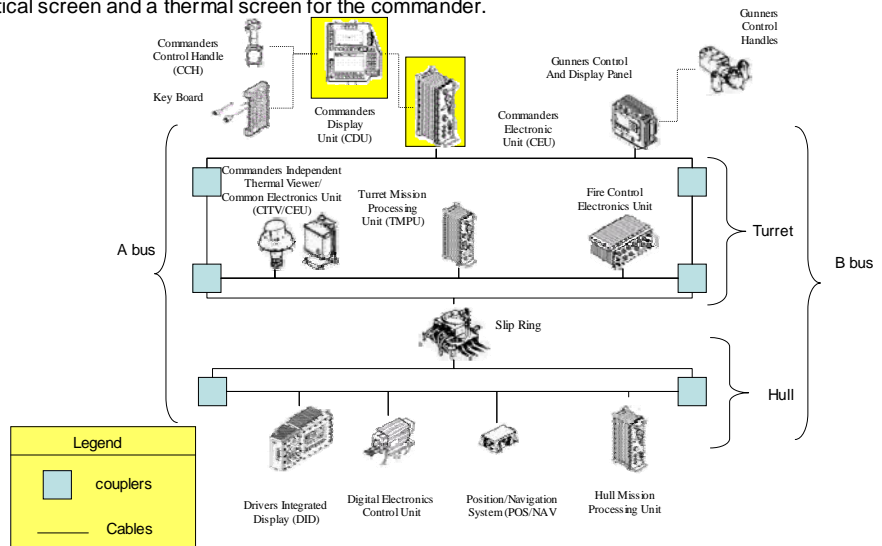
### Remote Terminal Commander's Independent Thermal Viewer/Common Electronics Unit CITV/CEU

The Function of the *Commander's Independent Thermal Viewer/ Common Electronics Unit (CITV/CEU)* is to provide the electronics to give the commander a separate stabilized thermal sight independent of turret movement and the Gunner's Primary Sight. It is independent of the Turret. It can automatically scan or be manually controlled by the commander.



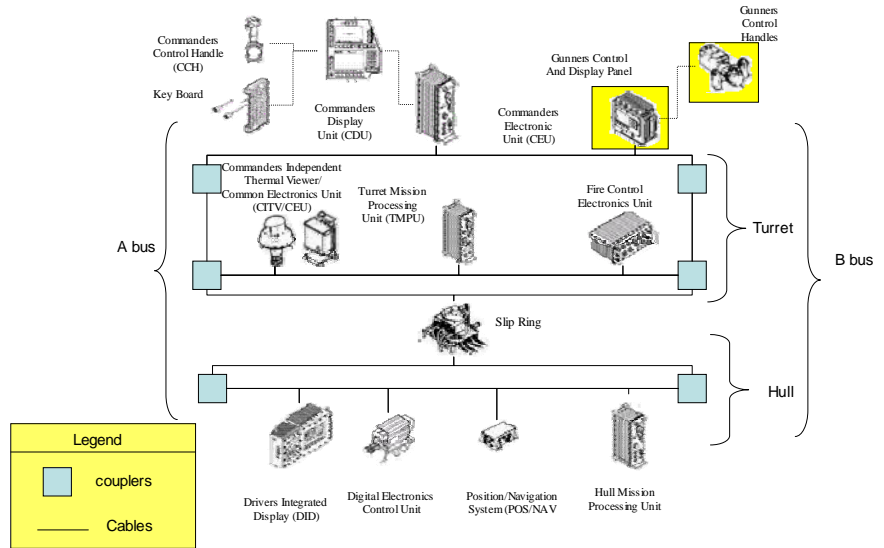
### Remote Terminal Commanders Electronic Unit (CEU)

The *Commanders Electronic Unit CEU* functions to provide the Processing and memory resources for the *Commander's Display Unit* and the command, control and communications functions. It allows for the control of the commander's displays and related databases and serves as the interface to commander controlled inter-vehicular functions like map display server. It also allows interface to common and new tank components and handles passwords, reconfiguration, and radio control through the 1553B bus. It allows operation of vehicle systems and provides a tactical screen and a thermal screen for the commander.



### Remote Terminal Gunners Control and Display Panel (GCDP)

The *Gunnery Control and Display Panel (GCDP)* provides the gunner with access to fire control functions and select backup functions for the commanders display unit. The GCDP converts analog signals from the *Gunner's Control Handles* to digital signals to be transmitted on the 1553B bus.



Begin taking test.  
Upon completion of test inform the monitor

## **APPENDIX B: SENTENCE COMPLETION**

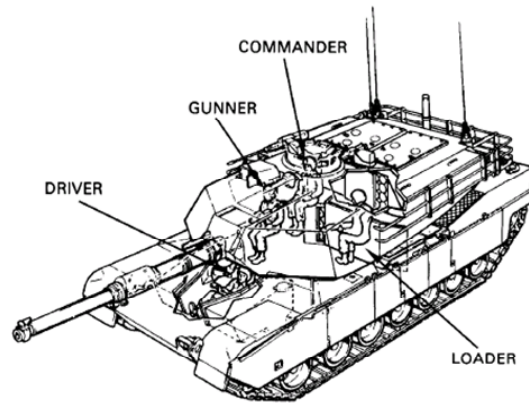
Please read the material at your own pace. During your reading, you will be asked to complete sentences intended to further your understanding of the material.

Good luck.

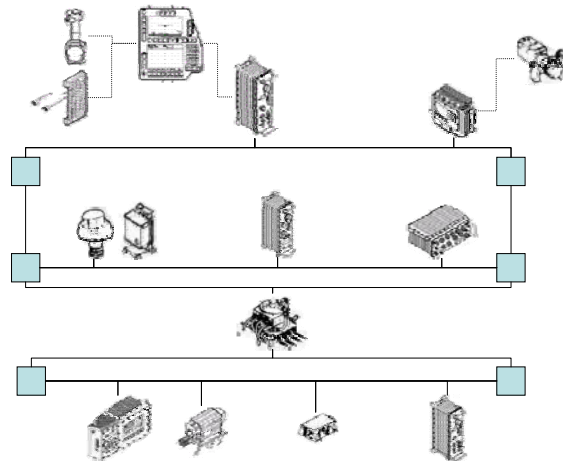
## M1A2 Tank Overview

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## M1A2 Tank Function

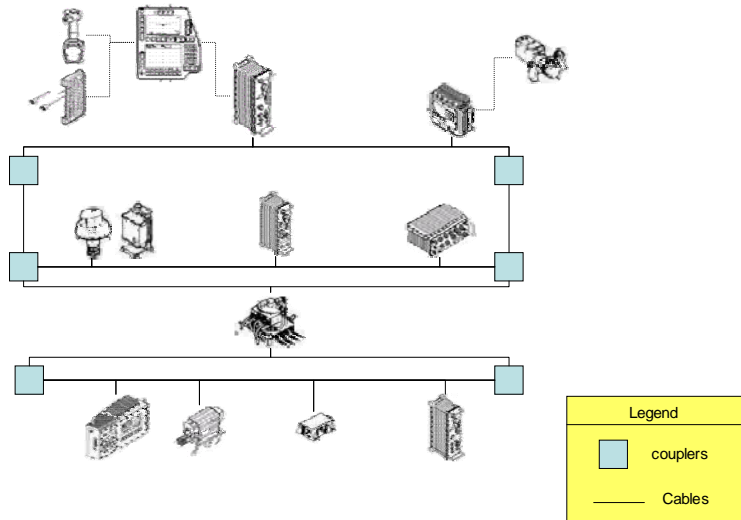


The M1A2 SEP tank system architecture is a set of distributed tank components interconnected to each other by a power distribution network and data distribution network(1553B Bus). This training will only address the 1553 Bus Data Distribution Network.



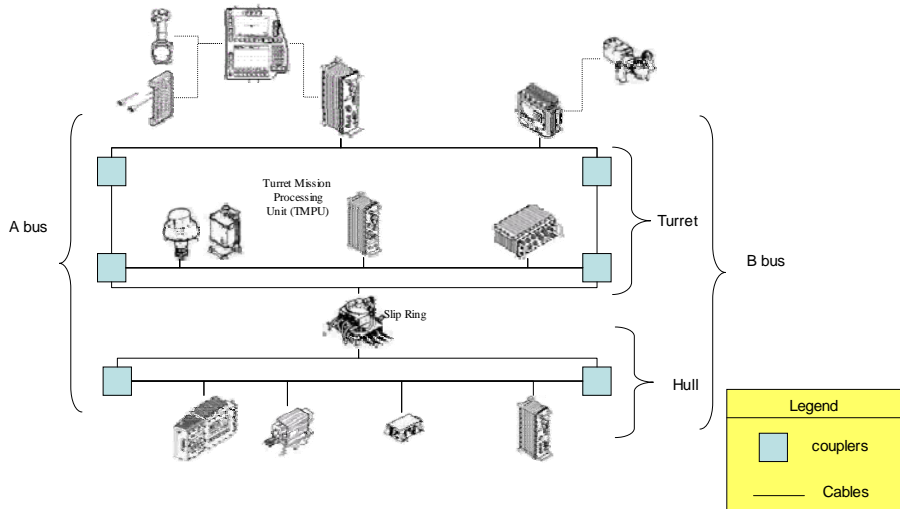
### 1553 Bus Function

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### 1553 Bus Mechanism

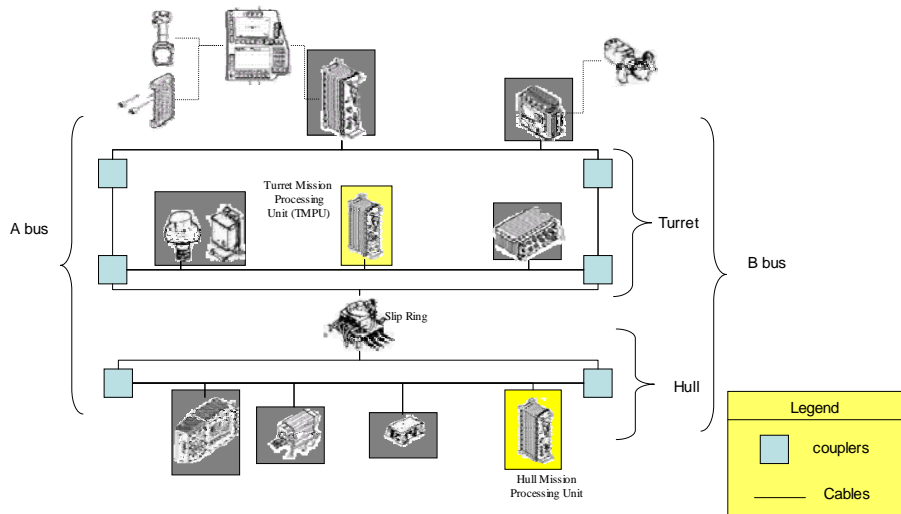
Mechanism: The 1553b data bus consist of a bus controller (also known as the Turret Mission Processor Unit) that *transmits and receives messages* across cables, through the slip ring and couplers. The controller communicates to a monitor and other remote terminals on this bus. This 1553b data bus is *dual redundant* with both an A bus and a B bus. It serves both turret functions and some hull functions.



**The 1553B dat bus controller is known as  
(Turret Mission Processor Unit, TMPU). It  
controls and monitors (functions) and  
(applications) of the tank.**

Function: The A and the B buses insure dual redundancy in the system. They distribute messages to all of *Remote Terminals* and the *Bus Monitor/Hull Mission Processing Unit (HMPU)* from and to the *Turret Mission Processing Unit (TMPU)*. If any bus is damaged the other bus, either the A or B bus which is not damaged, can still transmit information between the *Remote Terminals* and the *Turret Mission Processing Unit (TMPU)*.

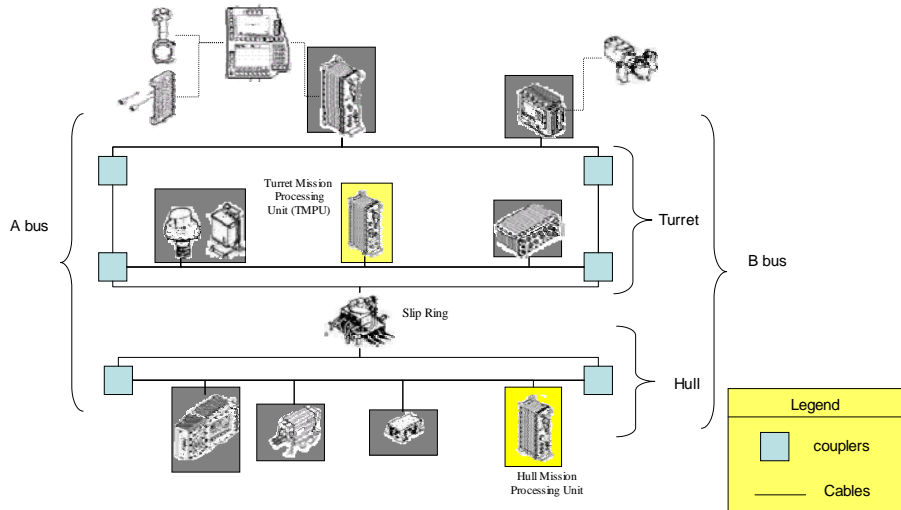
Mechanism: The A bus and B bus consist of a series of cables and couplers that connect the Bus Controller, *Bus Monitor* and *Remote Terminals*.



**The 1553B data bus is (dual redundant) which means that if either A or B bus is (damaged) the other working bus will take over and other (components) will not be effected.**

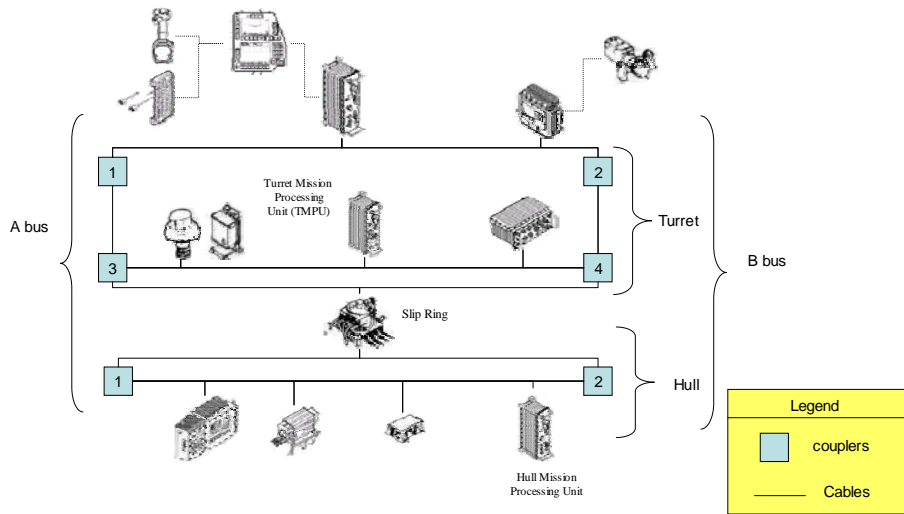
The A and B bus couplers distribute data and messages by bus cables to different Remote Terminals. They connect the *Bus Controller (Turret Mission Processing Unit TMPU)* and *Bus Monitor (Hull Mission Processing Unit HMPU)* to different *Remote Terminals*.

Bus Couplers isolate the A and B Bus to ensure that failure of one of the *Remote Terminal Units*, the *Turret Mission Processing Unit (TMPU)* or the *Hull Mission Processing Unit (HMPU)* will not result in main bus failure. They ACT AS A SURGE Protector protecting other components.

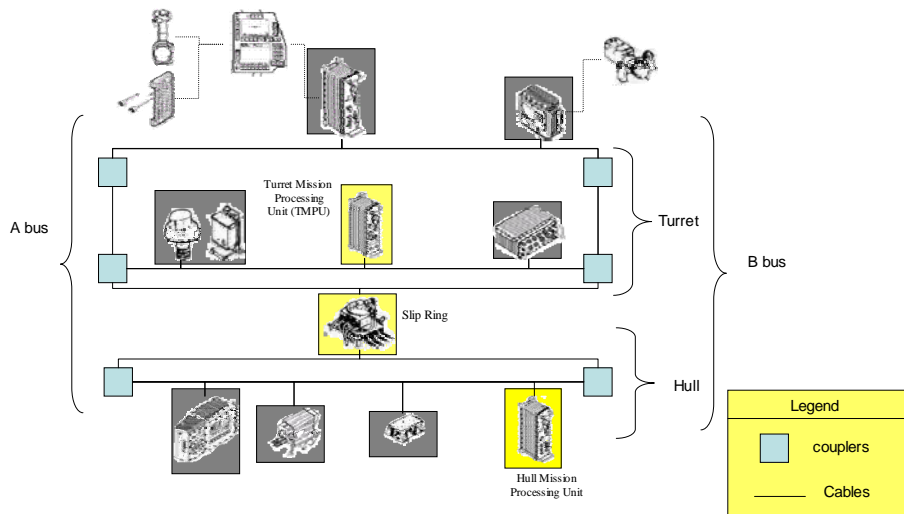


**Data and messages between remote terminals are carried-out by cables and passes through bus (couplers) which also act as (surge) protectors preventing failure of the (main bus) system.**

Four bus couplers are located in the *turret* and two are located in the *hull* in different locations. They are connected via cables and the slip ring. The couplers connected by cables routed along different paths to provide redundant capability.

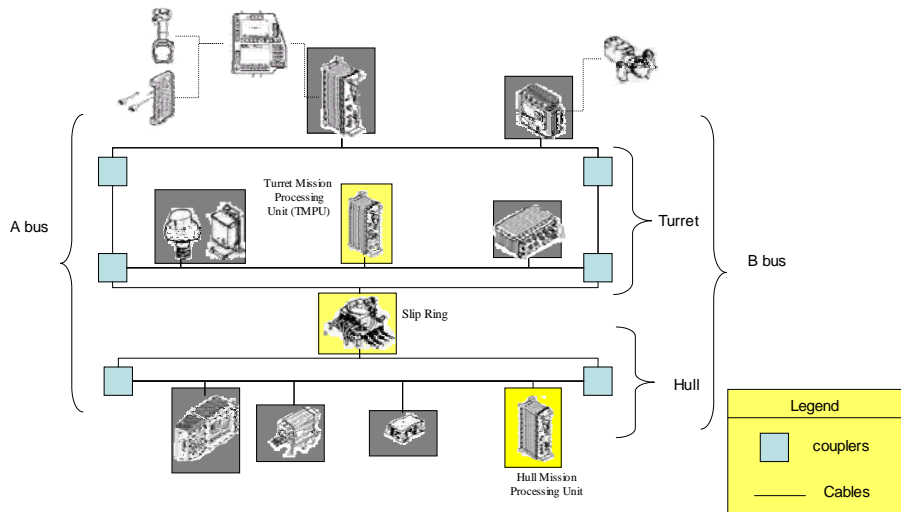


Function: The bus cables are the communication lines between the components of the bus system. They carry all information between components.



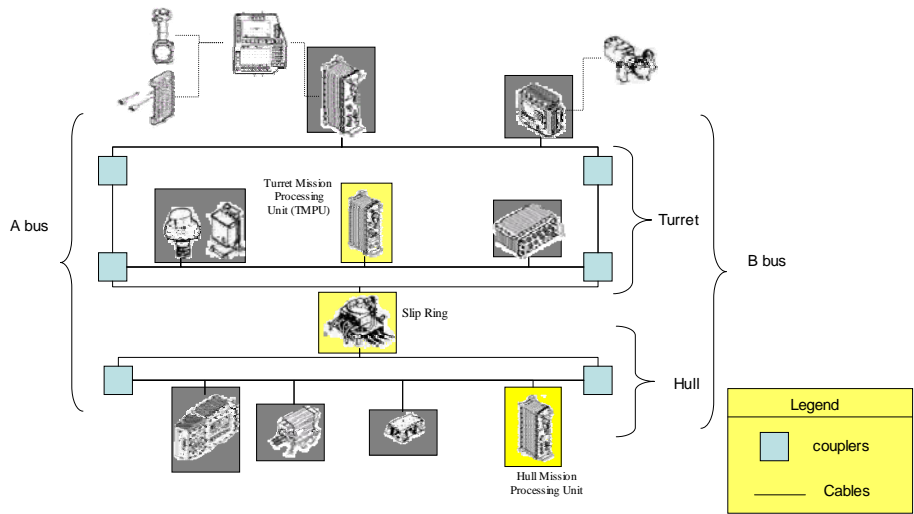
**(Information)** between the components of the  
bus system is carried out by (cables).

Mechanism: *Data bus cables* are a twisted pair of wires, which are shielded and connected to the *Turret Mission Processing Unit (TMPU)*, the *Hull Mission Processing Unit (HMPU)* and other *Remote Terminals*. The cables connect the *TMPU* and the *HMPU* and *Remote Terminals* to the *A bus couplers* and *B bus couplers*. Cables connect to the slip ring so the connection from the *turret* to the *hull* can be made. The cables are routed on different sides of the vehicle to provide redundant capability



**The (TMPU) and the (HMPU) are connected by means of (cables) and (couplers) through the (slip ring).**

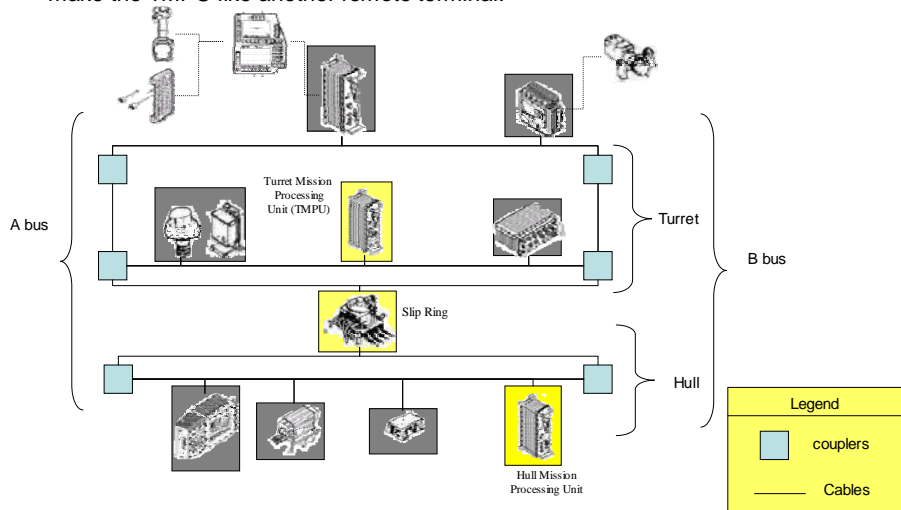
Function: The *Slip Ring* forms the communications link between the two A bus couplers and two B bus couplers which serve the Turret and one A bus coupler and one B bus coupler which serve the Hull.





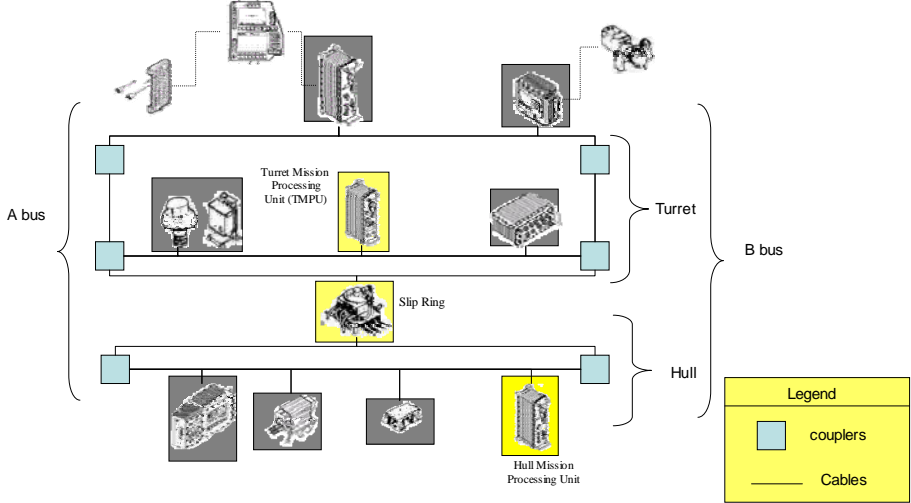
Function: The bus controller is referred to as the *Turret Mission Processing Unit (TMPU)*. It sends and controls the flow of messages across cables through couplers and their cables to remote terminals.

The *TMPU* is also responsible for conducting all system diagnostic checks and for calculating ballistic solutions for the tank under normal operations . These diagnostic and ballistic functions make the *TMPU* like another remote terminal.

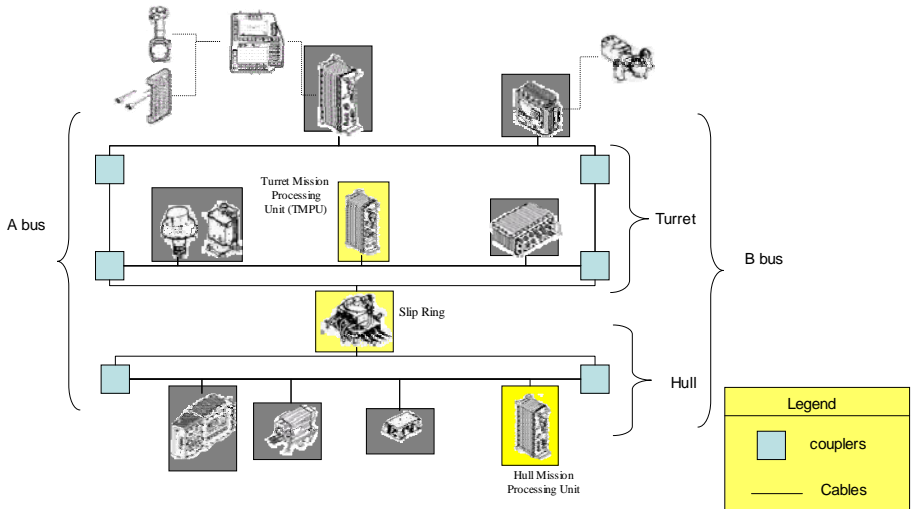


**The (TMPU) diagnose (faults) in components  
and calculate (ballistic) solutions.**

Mechanism: The *TMPU* communicates to *Remote Terminals* through redundant A and B buses. The *TMPU* consists of many computer processors which *control and manage* information transmission throughout the tank Turret systems and the Hull systems by way of cables and couplers. The *TMPU* talks to the *Bus Monitor* referred to as the *Hull Mission Processing Unit (HMPU)* through the A bus and B bus via the slip ring. The *TMPU* by way of the A and B buses can talk to all *Remote Terminals*, which perform various functions. The *TMPU* can control the talk between any two *Remote Terminals* by way of the A and B buses. Only one terminal can talk to one terminal at a time and the sequence in which any two terminals can talk is established by a fixed priority by the bus controller.

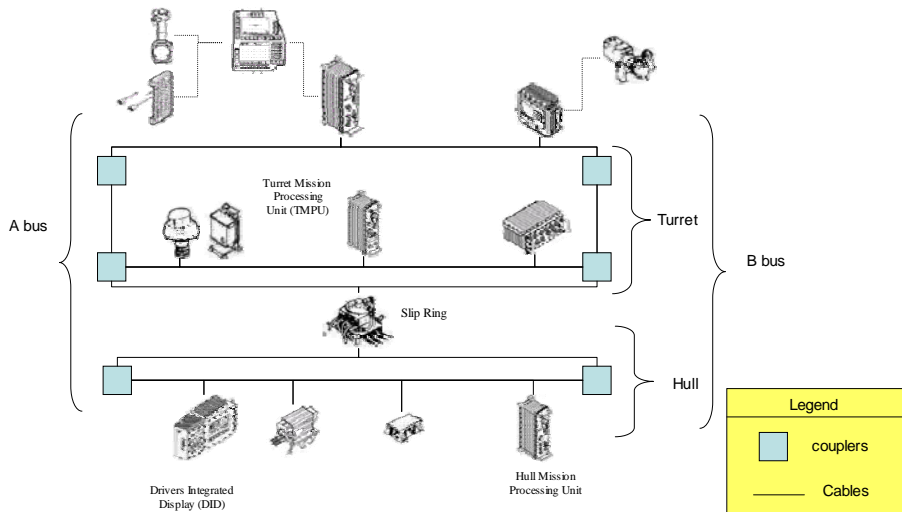


One of the *TMPU's* Remote Terminal functions is calculating ballistic solutions for the Fire Control System. It does this by storing and managing *critical data* such as Boresight data, plumb and sync., scan limits and rate, all drift data, ammo type, all zero data, Commander's Independent Thermal Viewer adjustments, and Sensor inputs for crosswind, cant, lead, ammo temperature and battle-sight range which is then used to *compute solutions for the fire control system employing the processors and the software of the TMPU.*



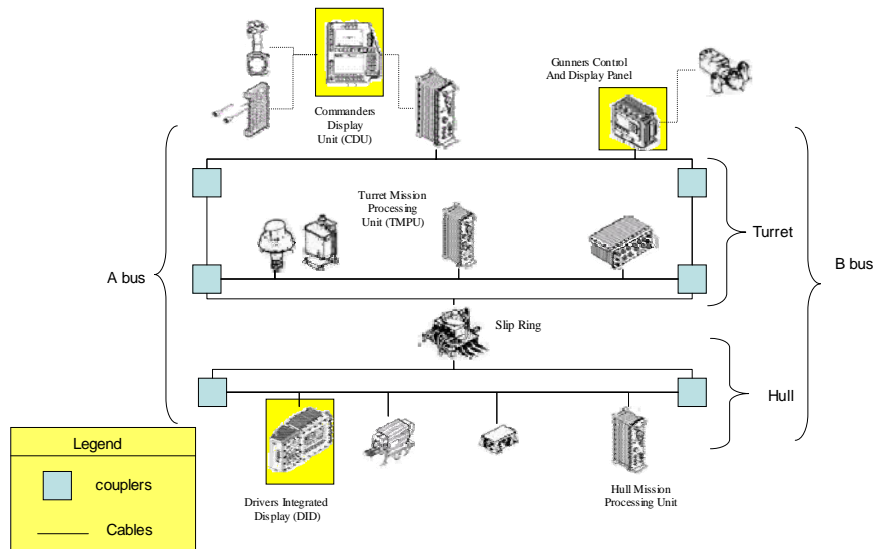
15 Remote Terminal Function of the Turret Mission Processing Unit: Diagnostic Group 1

Another Remote Terminal-like function of the Turret Mission Processing Unit (TMPU) is *diagnosing system components*. There are three different types of test, the *Self-Test (ST)*, the *Built in Test (BIT)* and the *Fault Isolation Test (FIT)*.



16 Remote Terminal Mechanism of the Turret Mission Processing Unit: Self Test Group 1

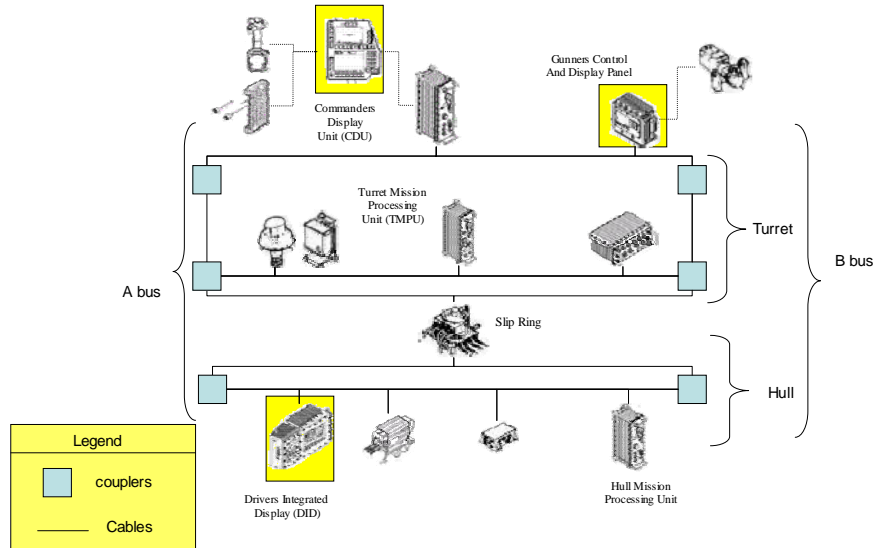
*Self-Test* is designed to run in the background without interfering with normal operations. If a fault is detected by the *Self-Test*, a caution or warning message is displayed in one of three locations; the *Commander's Display Unit*, the *Gunner's Control Display Panel* or the *Driver's Integrated Display*. This is an automatic test and runs constantly in the background.



**The (self-test) is run (automatically) in the background and does not (interfere) with the normal operations of the component.**

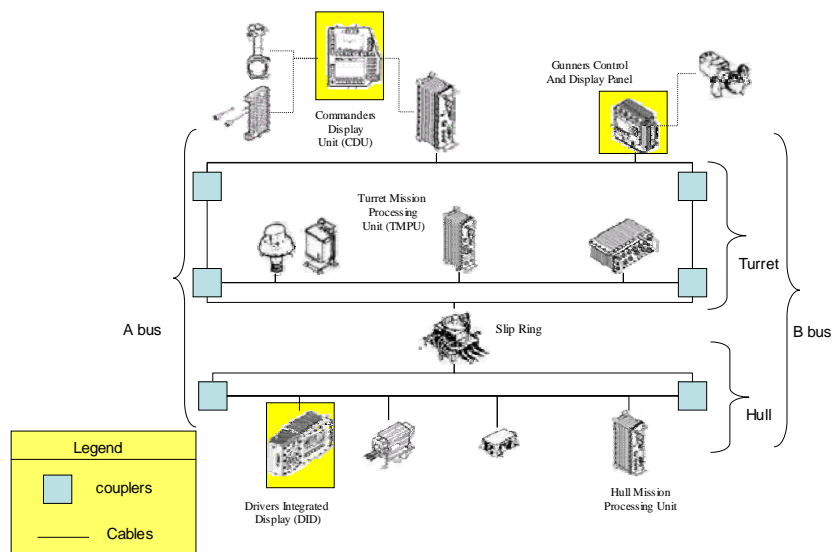
17 Remote Terminal Mechanism of the Turret Mission Processing Unit: Built In Test Group 1

The *Built in Test* is designed to provide extensive and comprehensive test coverage of the component in which the *BIT* is embedded. The *BIT* is an intrusive test which requires components to be shut down. When a fault is detected by *BIT* in its related component, it will display a NOGO message on the *Commander's Display Unit*, the *Gunner's Control Display Panel* or the *Driver's Integrated Display* to alert the crew or mechanic that a fault has occurred



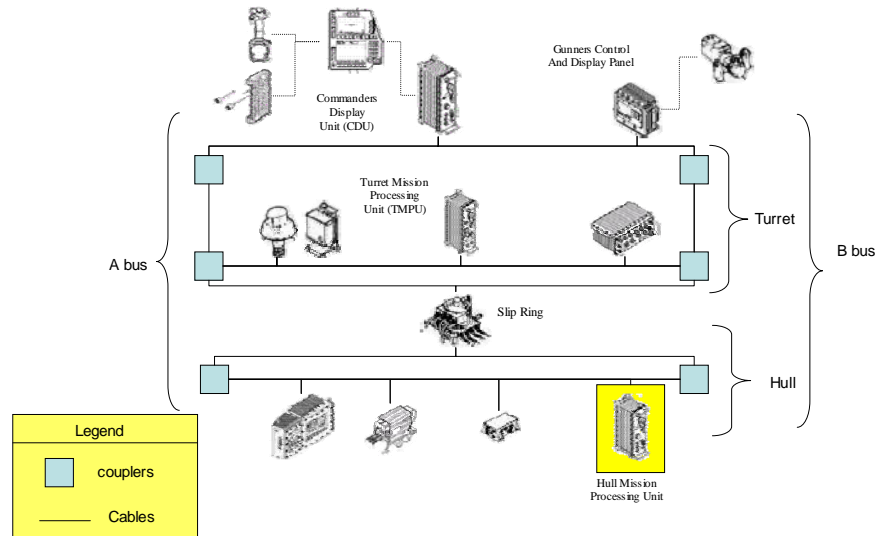
18 Remote Terminal Mechanism of the Turret Mission Processing Unit: Fault Isolation Test Group 1

The *Fault Isolation Test (FIT)* is designed to pinpoint a fault within a group of detected failures or support further testing of the system beyond the capabilities of the *Self-Test* or the *Built-In test*. Maintenance personnel will conduct *FIT* from the *Commander's Display Unit*, the *Gunner's Control Display Panel* or the *Driver's Integrated Display* depending upon the type of fault detected.



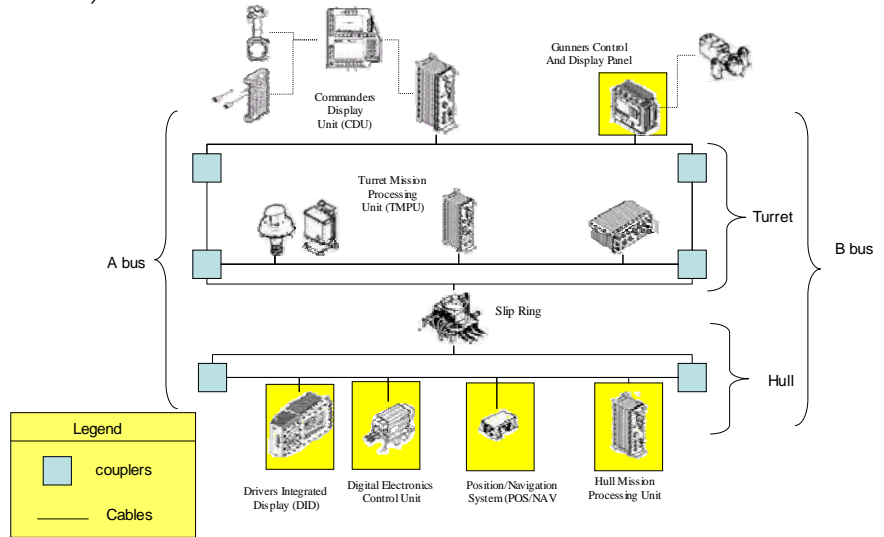
**The (Fault isolation Test) is performed by  
(maintenance) personnel to test components  
beyond the (capabilities) of the self-test and  
built in test.**

Function: The *Bus Monitor* or the *Hull Mission Processing Unit (HMPU)* is the *backup* for the *Bus Controller* or *Turret Mission Processing Unit (TMPU)*. If the *TMPU* fails, the *HMPU* can carry out all of the *Bus Controller* functions *except for the use of Global Positioning System information*. Global Positioning System information used for position information is fed directly to the *TMPU* and cannot be accessed by the *HMPU*. *This is the only function which is not dual redundant in the 1553B bus system*. The *HMPU*, like the *TMPU* can send messages across cables through couplers and their cables to remote terminals in the Hull and through cables, couplers and the slip ring to the remote terminals in the turret.



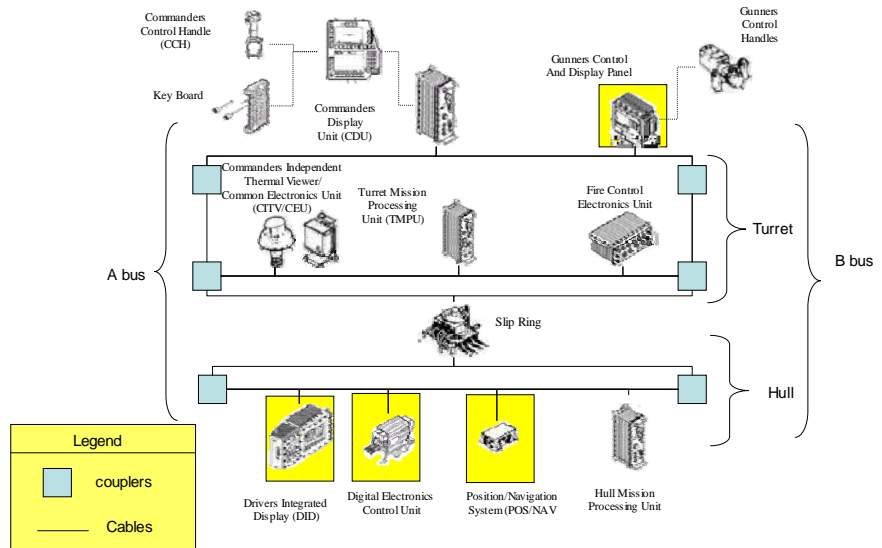
**The (Hull Mission Processing Unit, HMPU)**  
**can carry/backup all the functions of the**  
**(TMPU) except the use of the (Global**  
**Positioning System, GPS)**

Mechanism: The *Hull Mission Processing Unit (HMPU)* is also connected to two couplers one on the A bus and one on the B bus in the same way as the *Turret Mission Processing Unit (TMPU)*. This makes up six couplers in all with the addition of the two A and two B bus couplers of the Turret system. Three on the A bus and three on the B bus. The other Remote terminals which are connected along with the HMPU to these two couplers are: The *Driver's Integrated Display Unit (DID)*, the *Digital Electronics Control Unit (DECU)* and the *Position Navigation (POS/NAV) sensor*.



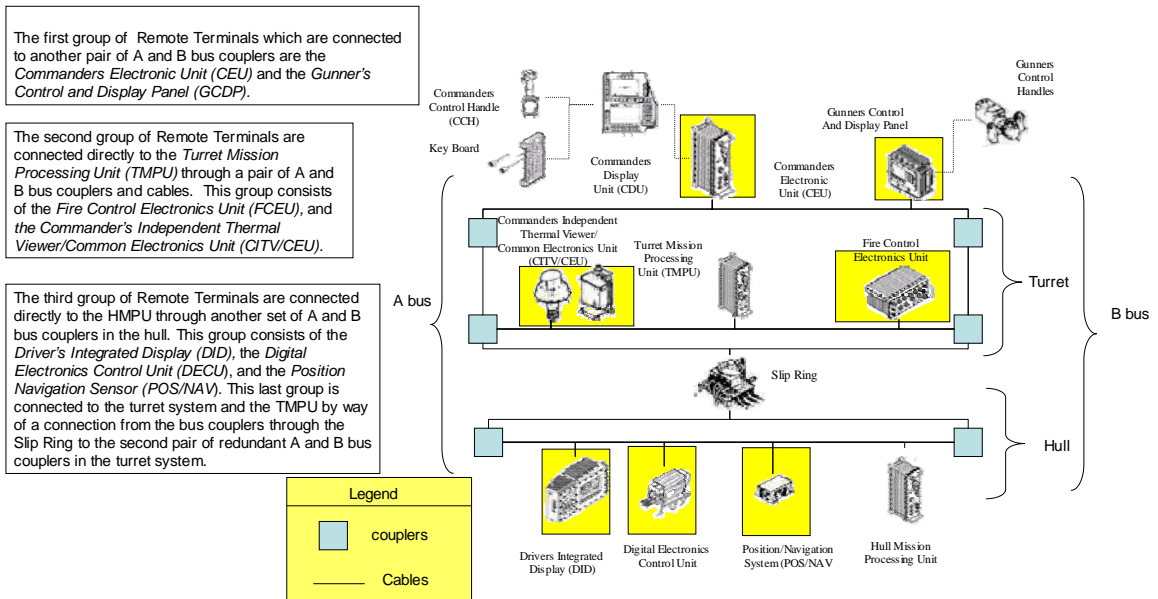


The *Remote Terminals* receive and transmit data on the bus in response to bus controller commands. They are connected to the A and B bus couplers in a specific way, such that, different Remote Terminals are connected to different A and B bus couplers. The couplers in turn are connected to each other on the A and B buses to route all information to the *TMPU* and the *HMPU*.



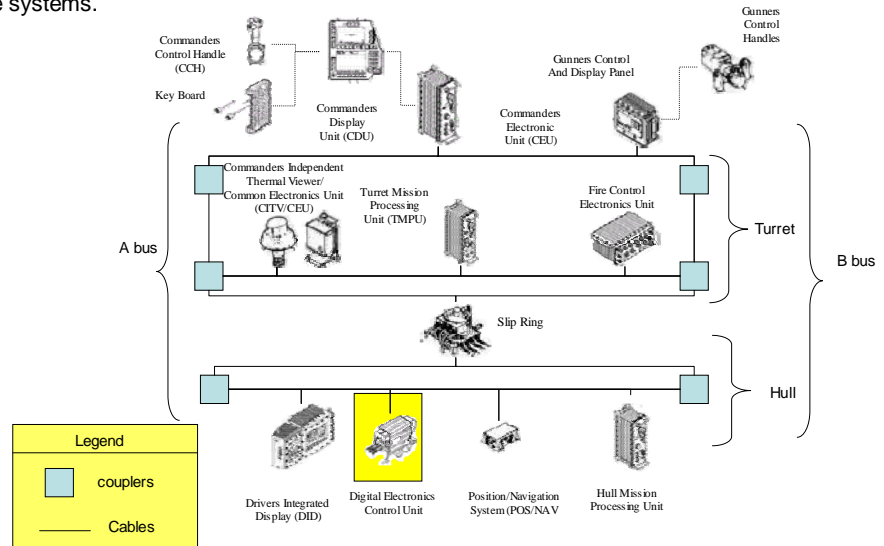
Mechanism of the Remote Terminals: The Remote Terminals are separated into three groups.

Each group of Remote Terminals is connected to a pair of A and B bus couplers.



. The Function of the Digital Electronics Control Unit (DECU):

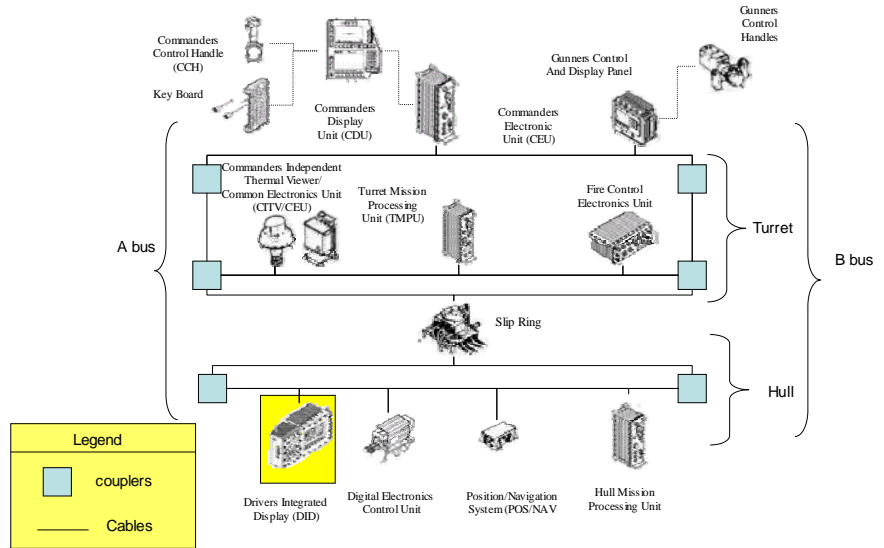
The function of the *Digital Electronics Control Unit (DECU)* is to control certain displays within the *Driver's Integrated Display* through the 1533B bus. The DECU converts analog to digital signals and provides control and monitoring of engine systems.



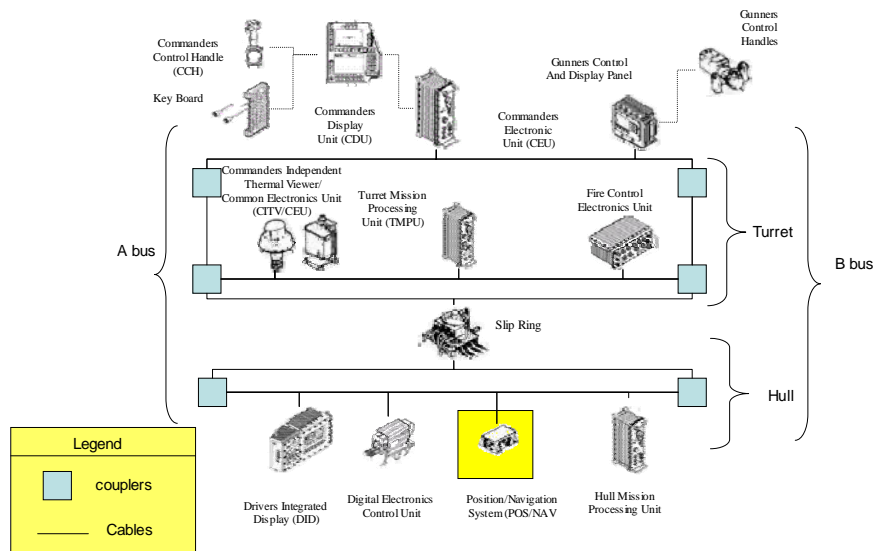
**The (Digital Electronics Control Unit, DECU)**  
**control other (displays), converts analog to**  
**(digital) signals, and control/monitor (engine**  
**systems)**

The Function of the *Driver's Integrated Display (DID)*:

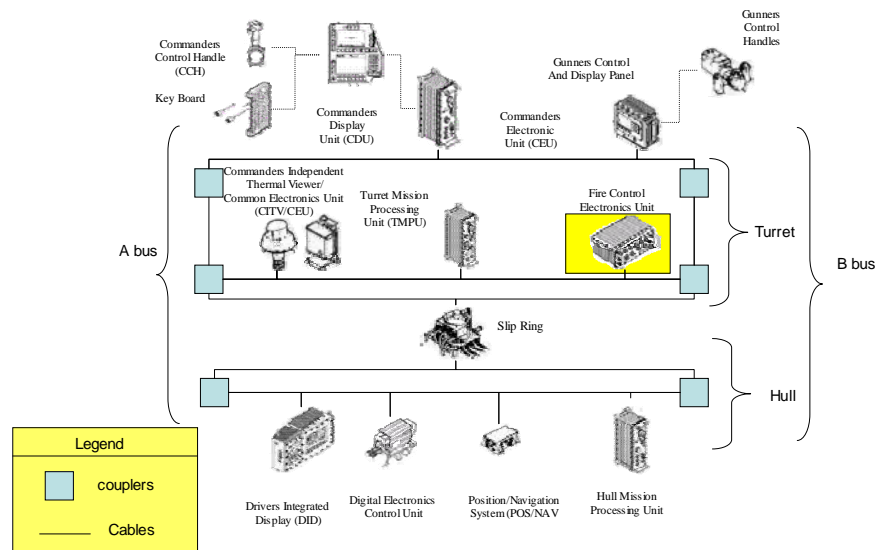
The function of the *DID* is to allow the driver access to all automotive related functions and to select back-up functions of the commander's display unit



The function of the *Position Navigation Sensor (POS/NAV)* is to provide movement and direction data for the commander, driver and the fire control system. It also provides *dynamic cant for the Fire Control System*.



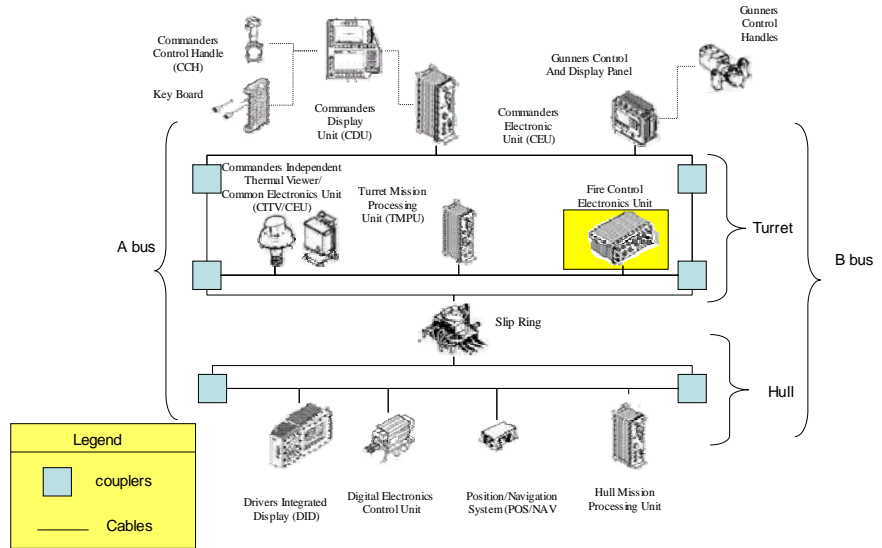
The function of the *Fire Control Electronics Unit (FCEU)*: is to integrate the Gunner's Primary Sight with the *Commander's Independent Thermal Viewer*. This allows the Commander to engage a target from the CITV or from the Gunners Primary Sight.



**The (FCEU) integrate the gunner's primary sight with the (CITV).**

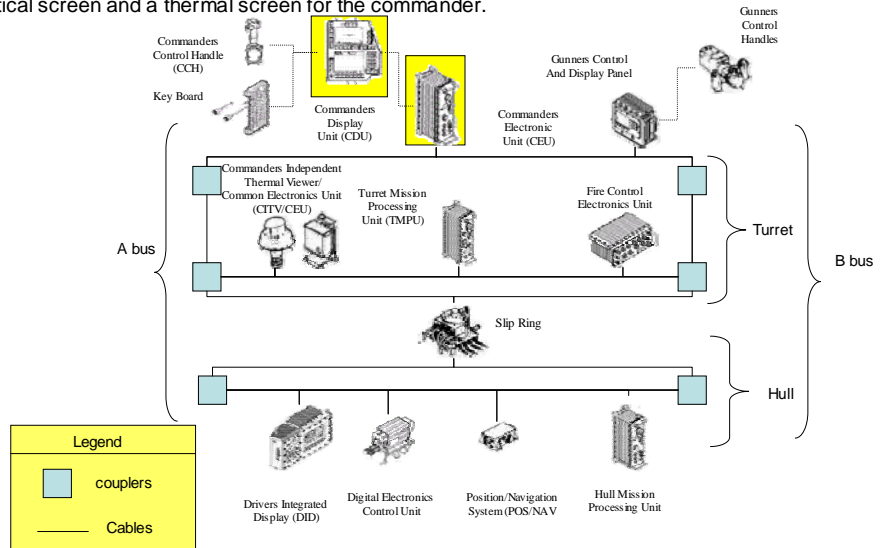
### Remote Terminal Commander's Independent Thermal Viewer/Common Electronics Unit CITV/CEU

The Function of the *Commander's Independent Thermal Viewer/ Common Electronics Unit (CITV/CEU)* is to provide the electronics to give the commander a separate stabilized thermal sight independent of turret movement and the Gunner's Primary Sight. It is independent of the Turret. It can automatically scan or be manually controlled by the commander.



### Remote Terminal Commanders Electronic Unit (CEU)

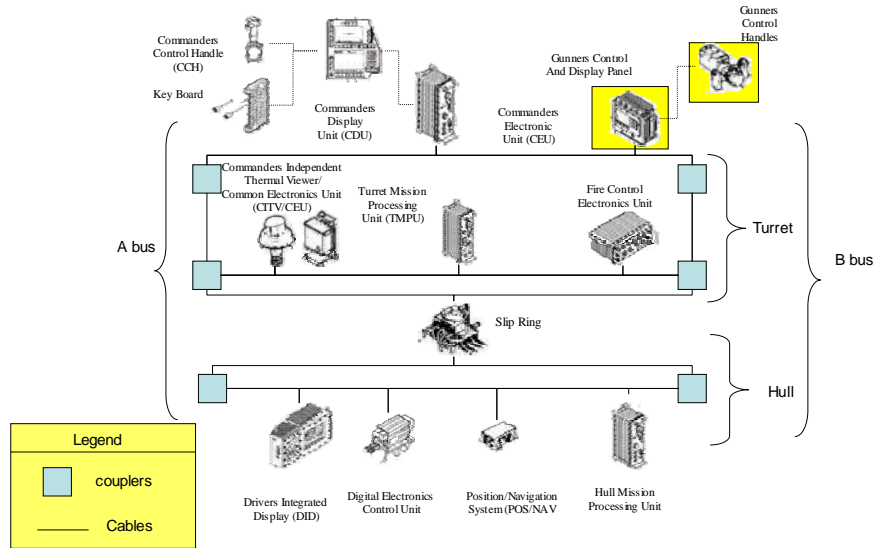
The *Commanders Electronic Unit CEU* functions to provide the Processing and memory resources for the *Commander's Display Unit* and the command, control and communications functions. It allows for the control of the commander's displays and related databases and serves as the interface to commander controlled inter-vehicular functions like map display server. It also allows interface to common and new tank components and handles passwords, reconfiguration, and radio control through the 1553B bus. It allows operation of vehicle systems and provides a tactical screen and a thermal screen for the commander.



**The Commanders Electronic Unit provide the  
(processing) and (memory) resources for the  
(Commanders Display Unit).**

### Remote Terminal Gunners Control and Display Panel (GCDP)

The *Gunnery Control and Display Panel (GCDP)* provides the gunner with access to fire control functions and select backup functions for the commanders display unit. The GCDP converts analog signals from the *Gunner's Control Handles* to digital signals to be transmitted on the 1553B bus.



Begin taking test.  
Upon completion of test inform the monitor

## **APPENDIX C: SENTENCE GENERATION**



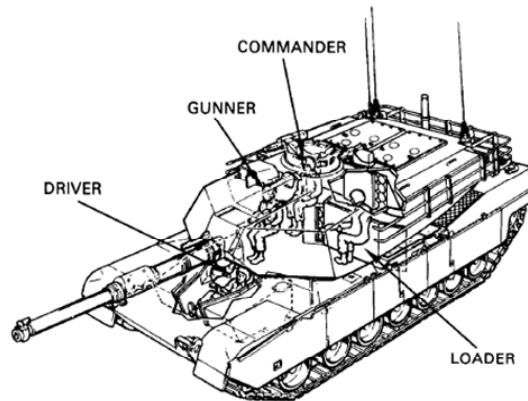
Please read the material at your own pace. During your reading, you will be asked to write sentences using key words from the curriculum and intended to further your understanding of the material.

Good luck.

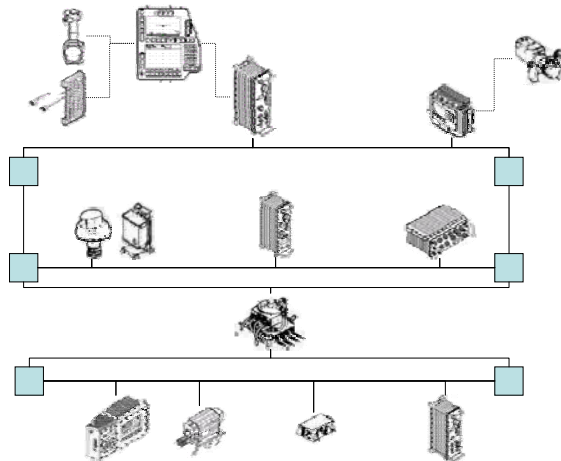
## M1A2 Tank Overview

### Objective: Familiarization with the M1A2 Tank

The M1A2 SEP combat tank uses high speed, maneuverability, and a variety of weapons to accomplish its mission. The tank provides protection from enemy weapons. It has a crew of four individuals. The driver is located in the hull the Gunner, Commander and Loader are Located in the Turret. This training will focus on the 1553B it is the data communications component of the M1A1SEP



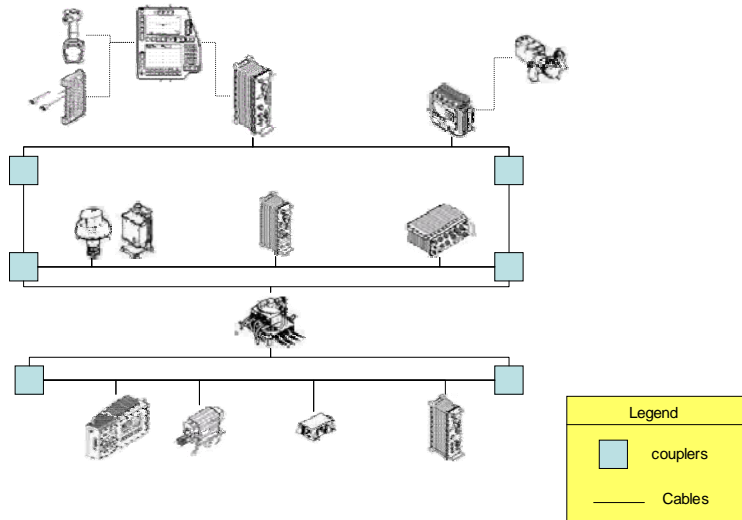
## M1A2 Tank Function



The M1A2 SEP tank system architecture is a set of distributed tank components interconnected to each other by a power distribution network and data distribution network(1553B Bus). This training will only address the 1553 Bus Data Distribution Network.

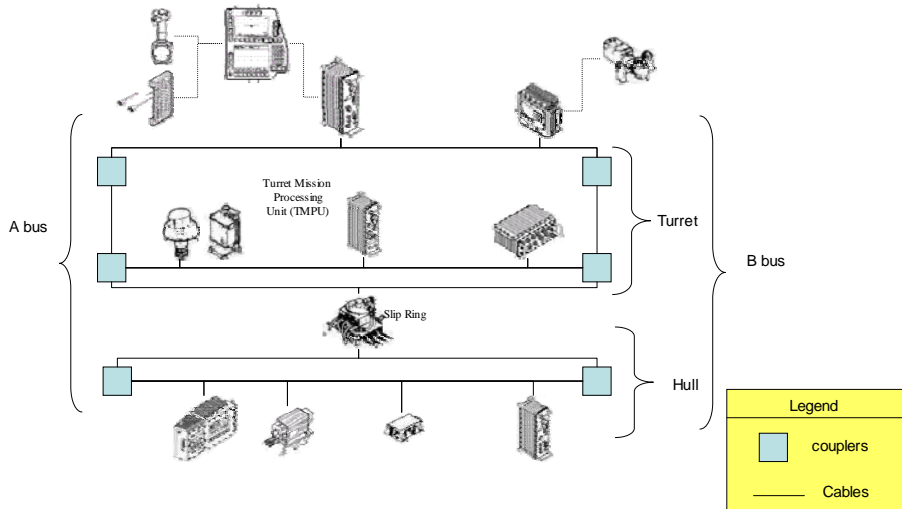
### 1553 Bus Function

Function: The 1553B Data Bus communicates all data messages to *control* and *monitor the functions and applications* of the tank. The diagram has all of the components of the 1553 Data Bus along with the wires and couplers that make up the data bus.



### 1553 Bus Mechanism

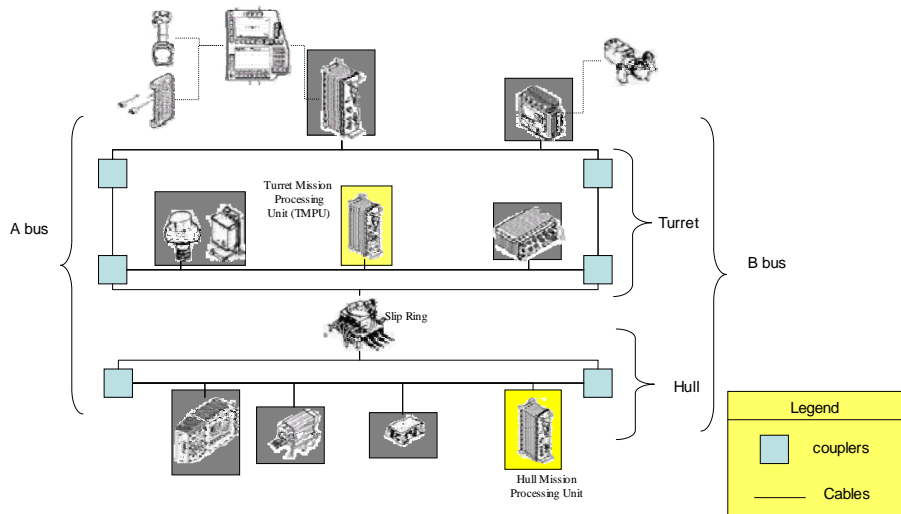
Mechanism: The 1553b data bus consist of a bus controller (also known as the Turret Mission Processor Unit) that *transmits and receives messages* across cables, through the slip ring and couplers. The controller communicates to a monitor and other remote terminals on this bus. This 1553b data bus is *dual redundant* with both an A bus and a B bus. It serves both turret functions and some hull functions.



**Generate a sentence using: (Turret Mission Processor Unit), (functions), and (applications).**

Function: The A and the B buses insure dual redundancy in the system. They distribute messages to all of *Remote Terminals* and the *Bus Monitor/Hull Mission Processing Unit (HMPU)* from and to the *Turret Mission Processing Unit (TMPU)*. If any bus is damaged the other bus, either the A or B bus which is not damaged, can still transmit information between the *Remote Terminals* and the *Turret Mission Processing Unit (TMPU)*.

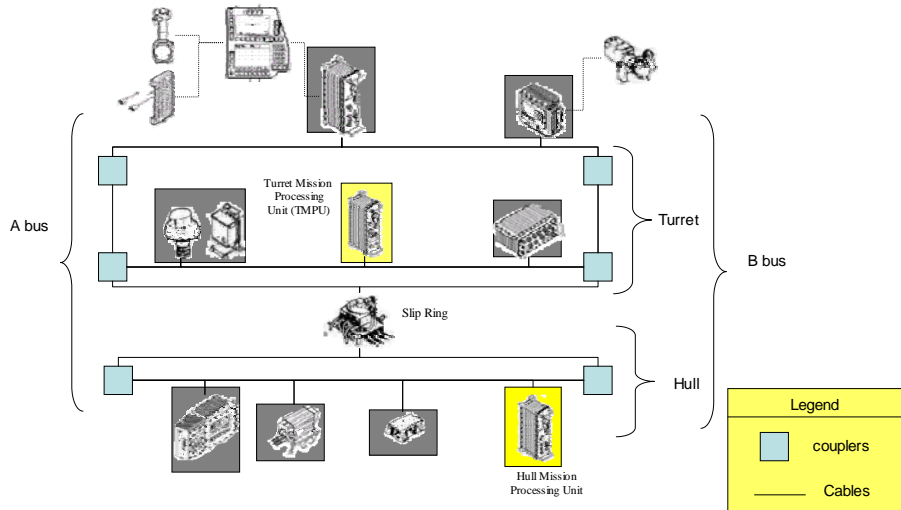
Mechanism: The A bus and B bus consist of a series of cables and couplers that connect the Bus Controller, *Bus Monitor* and *Remote Terminals*.



**Generate a sentence using: (dual redundant), (damaged), and (components).**

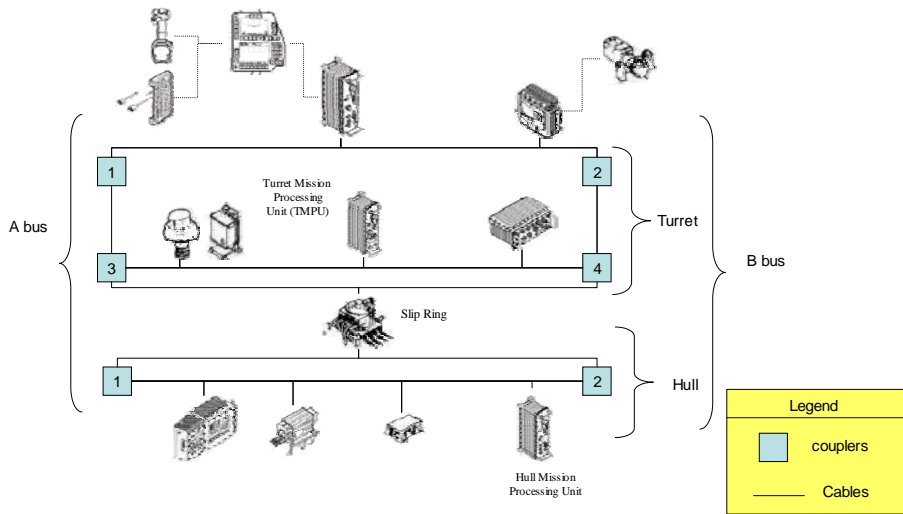
The A and B bus couplers distribute data and messages by bus cables to different Remote Terminals. They connect the *Bus Controller (Turret Mission Processing Unit TMPU)* and *Bus Monitor (Hull Mission Processing Unit HMPU)* to different *Remote Terminals*.

Bus Couplers isolate the A and B Bus to ensure that failure of one of the *Remote Terminal Units*, the *Turret Mission Processing Unit (TMPU)* or the *Hull Mission Processing Unit (HMPU)* will not result in main bus failure. They ACT AS A SURGE Protector protecting other components.

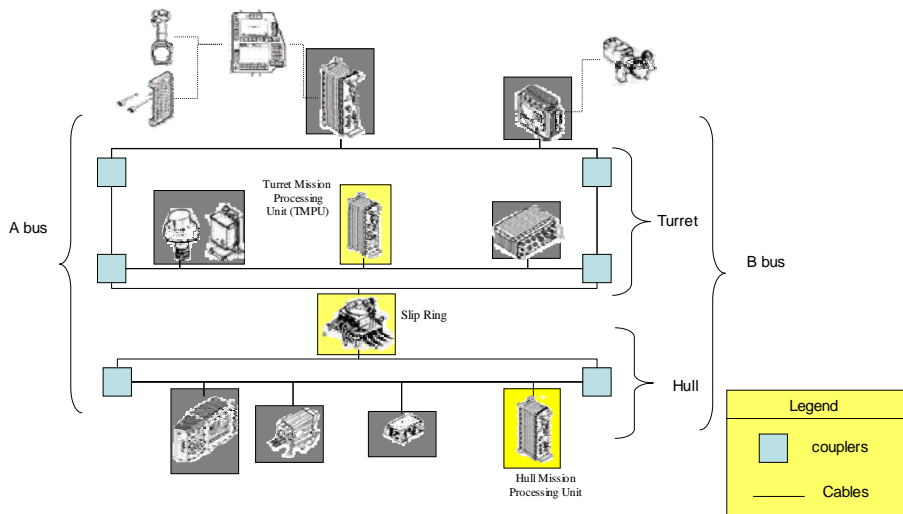


**Generate a sentence using: (surge), (main bus), and (couplers).**

Four bus couplers are located in the *turret* and two are located in the *hull* in different locations. They are connected via cables and the slip ring. The couplers connected by cables routed along different paths to provide redundant capability.



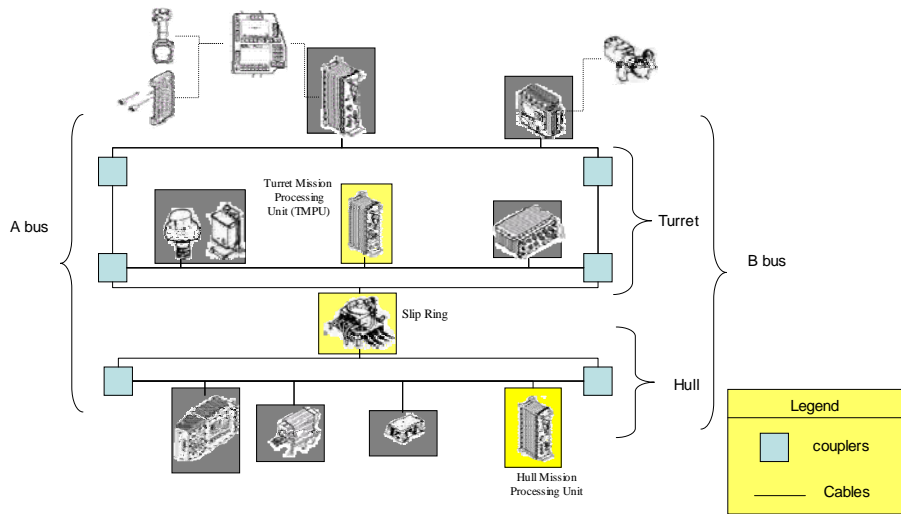
Function: The bus cables are the communication lines between the components of the bus system. They carry all information between components.



**Generate a sentence using: (information) and  
(cables).**

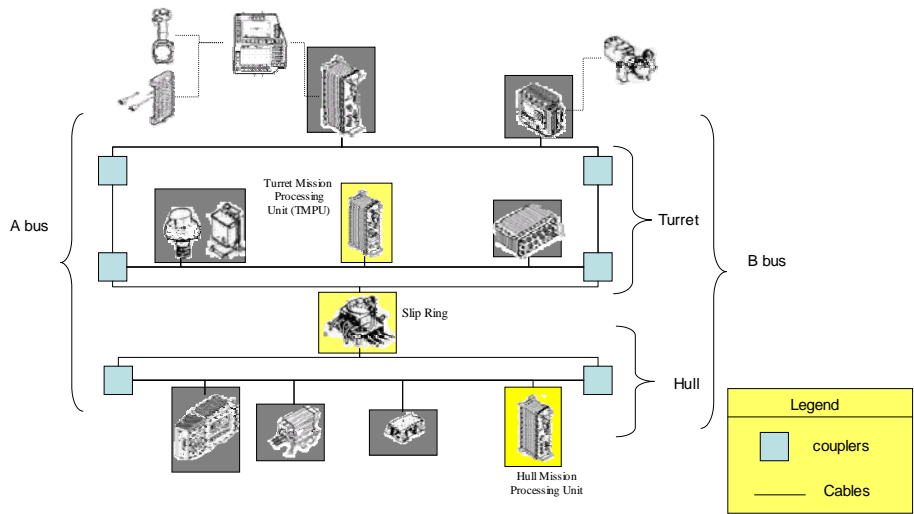


Mechanism: *Data bus cables* are a twisted pair of wires, which are shielded and connected to the *Turret Mission Processing Unit (TMPU)*, the *Hull Mission Processing Unit (HMPU)* and other *Remote Terminals*. The cables connect the *TMPU* and the *HMPU* and *Remote Terminals* to the *A bus couplers* and *B bus couplers*. Cables connect to the slip ring so the connection from the *turret* to the *hull* can be made. The cables are routed on different sides of the vehicle to provide redundant capability



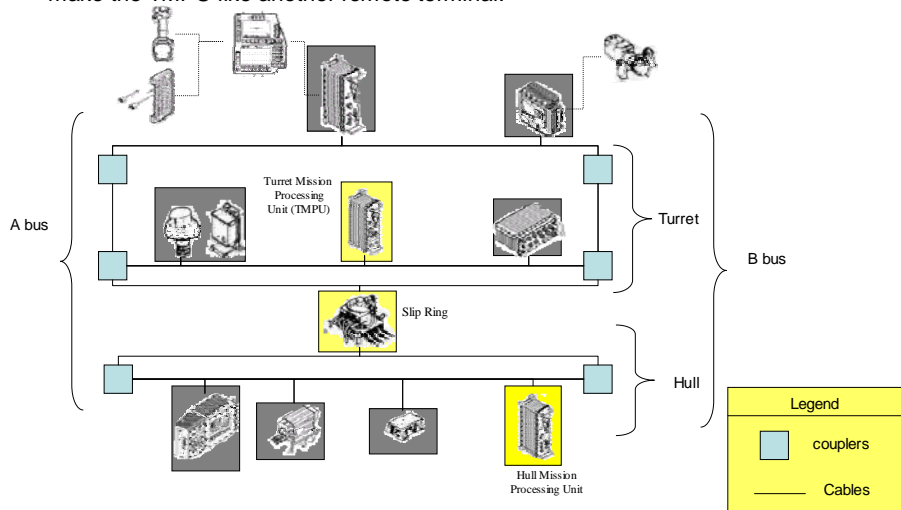
**Generate a sentence using: (TMPU), (HMPU),  
(cables), (couplers), and (slip ring).**

Function: The *Slip Ring* forms the communications link between the two A bus couplers and two B bus couplers which serve the Turret and one A bus coupler and one B bus coupler which serve the Hull.



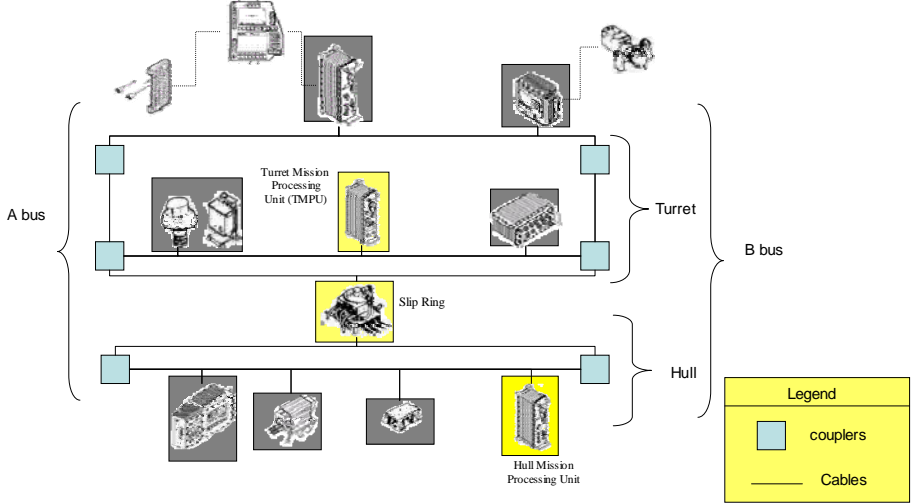
Function: The bus controller is referred to as the *Turret Mission Processing Unit (TMPU)*. It sends and controls the flow of messages across cables through couplers and their cables to remote terminals.

The *TMPU* is also responsible for conducting all system diagnostic checks and for calculating ballistic solutions for the tank under normal operations . These diagnostic and ballistic functions make the *TMPU* like another remote terminal.

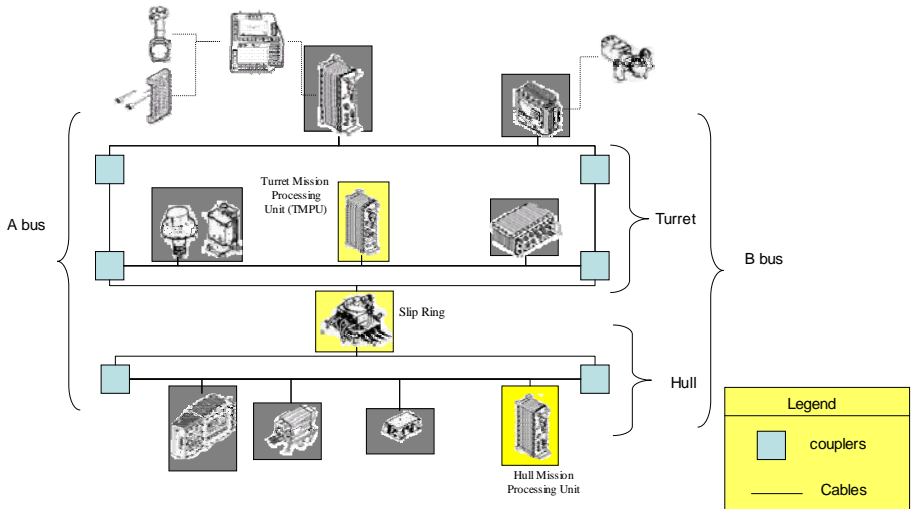


**Generate a sentence using: (TMPU), (faults),  
and (ballistic) solutions.**

Mechanism: The *TMPU* communicates to *Remote Terminals* through redundant A and B buses. The *TMPU* consists of many computer processors which *control and manage* information transmission throughout the tank Turret systems and the Hull systems by way of cables and couplers. The *TMPU* talks to the *Bus Monitor* referred to as the *Hull Mission Processing Unit (HMPU)* through the A bus and B bus via the slip ring. The *TMPU* by way of the A and B buses can talk to all *Remote Terminals*, which perform various functions. The *TMPU* can control the talk between any two *Remote Terminals* by way of the A and B buses. Only one terminal can talk to one terminal at a time and the sequence in which any two terminals can talk is established by a fixed priority by the bus controller.

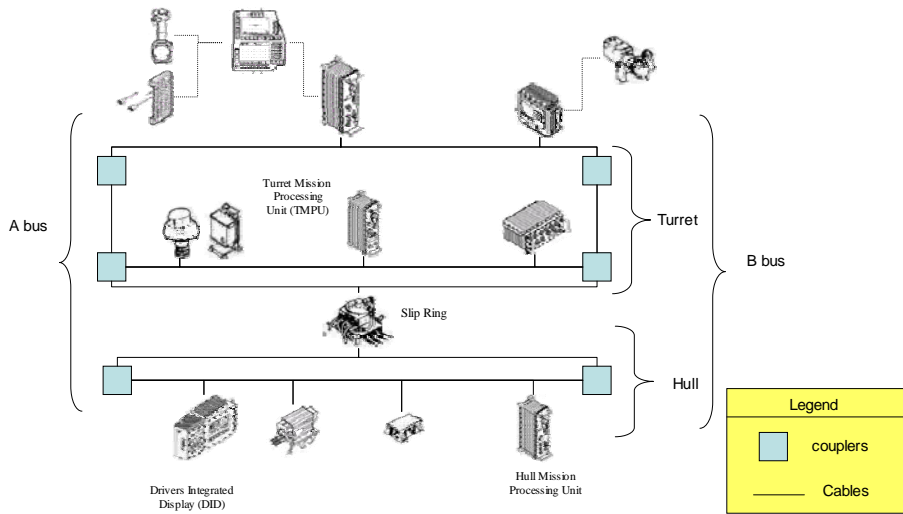


One of the *TMPU's* Remote Terminal functions is calculating ballistic solutions for the Fire Control System. It does this by storing and managing *critical data* such as Boresight data, plumb and sync., scan limits and rate, all drift data, ammo type, all zero data, Commander's Independent Thermal Viewer adjustments, and Sensor inputs for crosswind, cant, lead, ammo temperature and battle-sight range which is then used to *compute solutions for the fire control system employing the processors and the software of the TMPU.*



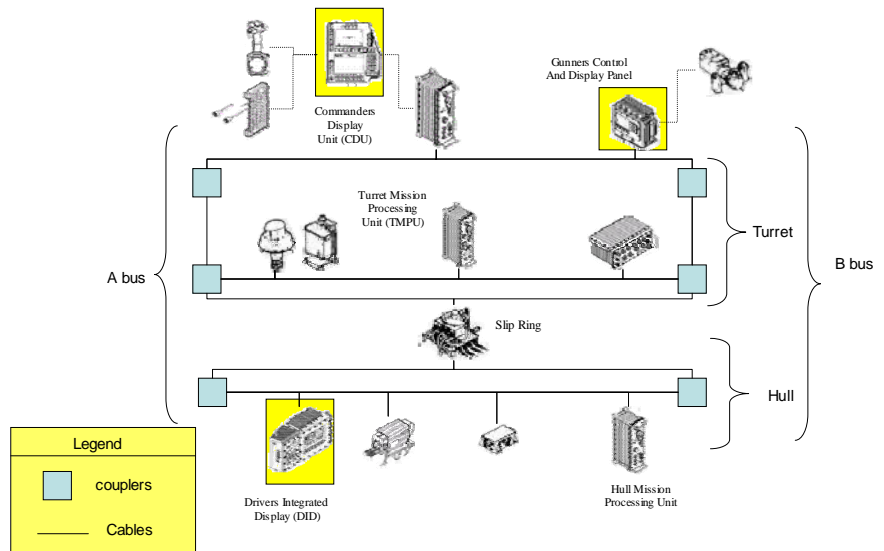
15 Remote Terminal Function of the Turret Mission Processing Unit: Diagnostic Group 1

Another Remote Terminal-like function of the Turret Mission Processing Unit (TMPU) is *diagnosing system components*. There are three different types of test, the *Self-Test (ST)*, the *Built in Test (BIT)* and the *Fault Isolation Test (FIT)*.



16 Remote Terminal Mechanism of the Turret Mission Processing Unit: Self Test Group 1

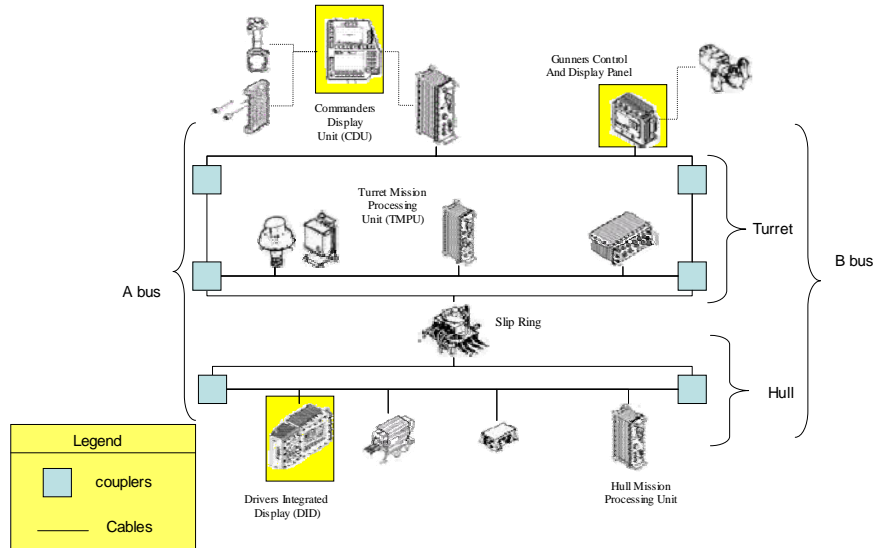
*Self-Test* is designed to run in the background without interfering with normal operations. If a fault is detected by the *Self-Test*, a caution or warning message is displayed in one of three locations; the *Commander's Display Unit*, the *Gunner's Control Display Panel* or the *Driver's Integrated Display*. This is an automatic test and runs constantly in the background.



**Generate a sentence using: (self-test),  
(automatically), and (interfere).**

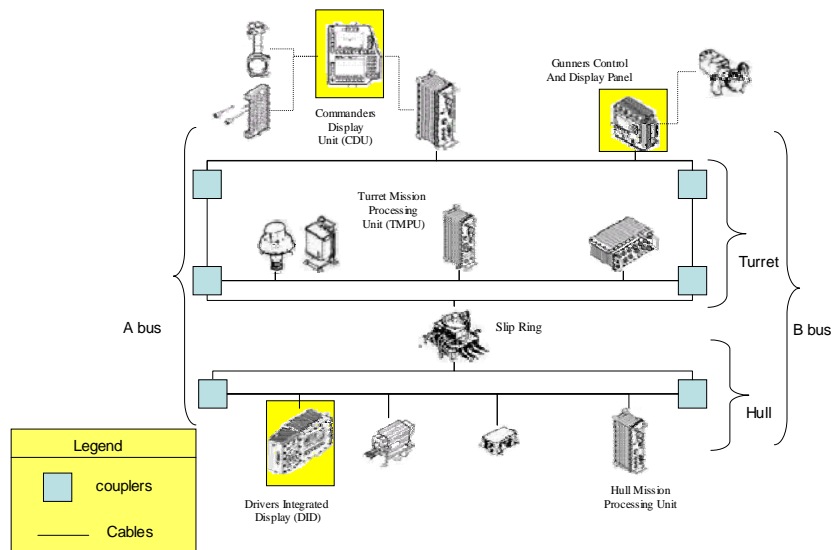
17 Remote Terminal Mechanism of the Turret Mission Processing Unit: Built In Test Group 1

The *Built in Test* is designed to provide extensive and comprehensive test coverage of the component in which the *BIT* is embedded. The *BIT* is an intrusive test which requires components to be shut down. When a fault is detected by *BIT* in its related component, it will display a NOGO message on the *Commander's Display Unit*, the *Gunner's Control Display Panel* or the *Driver's Integrated Display* to alert the crew or mechanic that a fault has occurred



18 Remote Terminal Mechanism of the Turret Mission Processing Unit: Fault Isolation Test Group 1

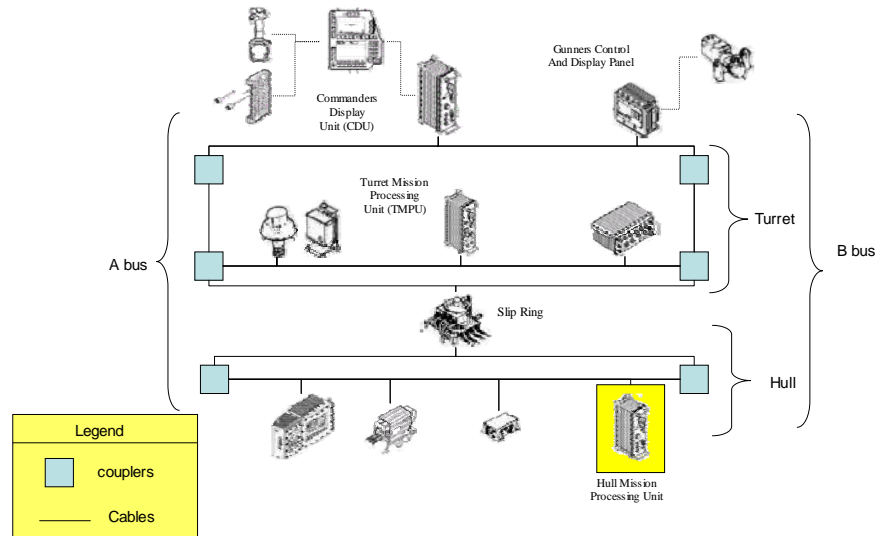
The *Fault Isolation Test (FIT)* is designed to pinpoint a fault within a group of detected failures or support further testing of the system beyond the capabilities of the *Self-Test* or the *Built-In test*. Maintenance personnel will conduct *FIT* from the *Commander's Display Unit*, the *Gunner's Control Display Panel* or the *Driver's Integrated Display* depending upon the type of fault detected.



**Generate a sentence using: (Fault isolation  
Test), (capabilities), (maintenance).**

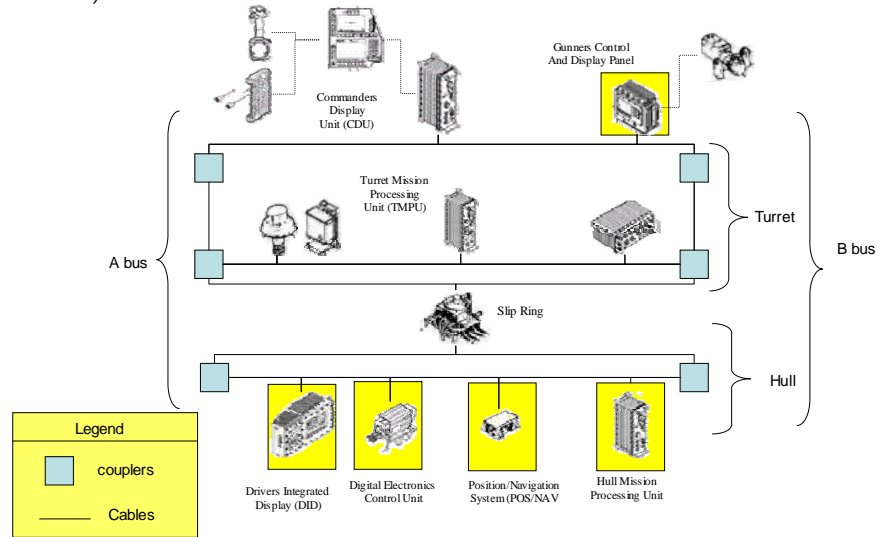


Function: The *Bus Monitor* or the *Hull Mission Processing Unit (HMPU)* is the *backup* for the *Bus Controller* or *Turret Mission Processing Unit (TMPU)*. If the *TMPU* fails, the *HMPU* can carry out all of the *Bus Controller* functions *except for the use of Global Positioning System information*. Global Positioning System information used for position information is fed directly to the *TMPU* and cannot be accessed by the *HMPU*. *This is the only function which is not dual redundant in the 1553B bus system*. The *HMPU*, like the *TMPU* can send messages across cables through couplers and their cables to remote terminals in the Hull and through cables, couplers and the slip ring to the remote terminals in the turret.

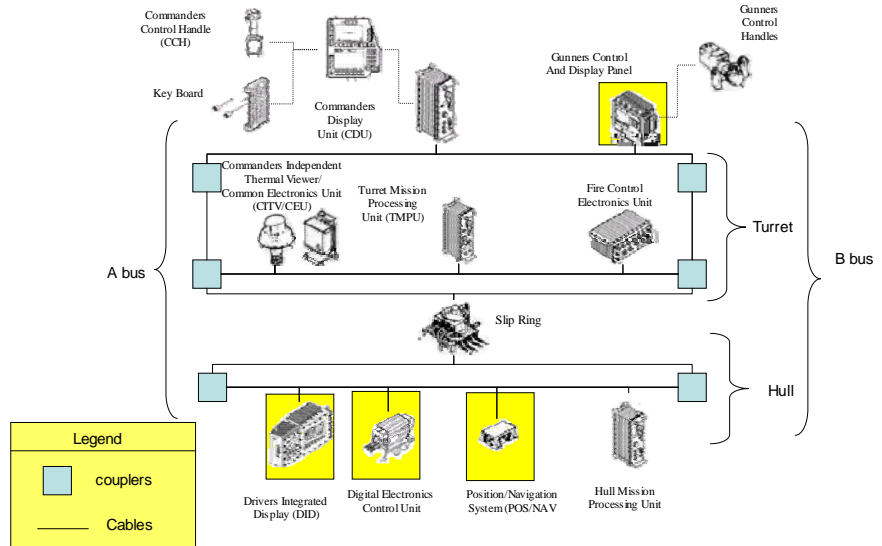


**Generate a sentence using: (HMPU), (TMPU) and (GPS).**

Mechanism: The *Hull Mission Processing Unit (HMPU)* is also connected to two couplers one on the A bus and one on the B bus in the same way as the *Turret Mission Processing Unit (TMPU)*. This makes up six couplers in all with the addition of the two A and two B bus couplers of the Turret system. Three on the A bus and three on the B bus. The other Remote terminals which are connected along with the HMPU to these two couplers are: The *Driver's Integrated Display Unit (DID)*, the *Digital Electronics Control Unit (DECU)* and the *Position Navigation (POS/NAV) sensor*.

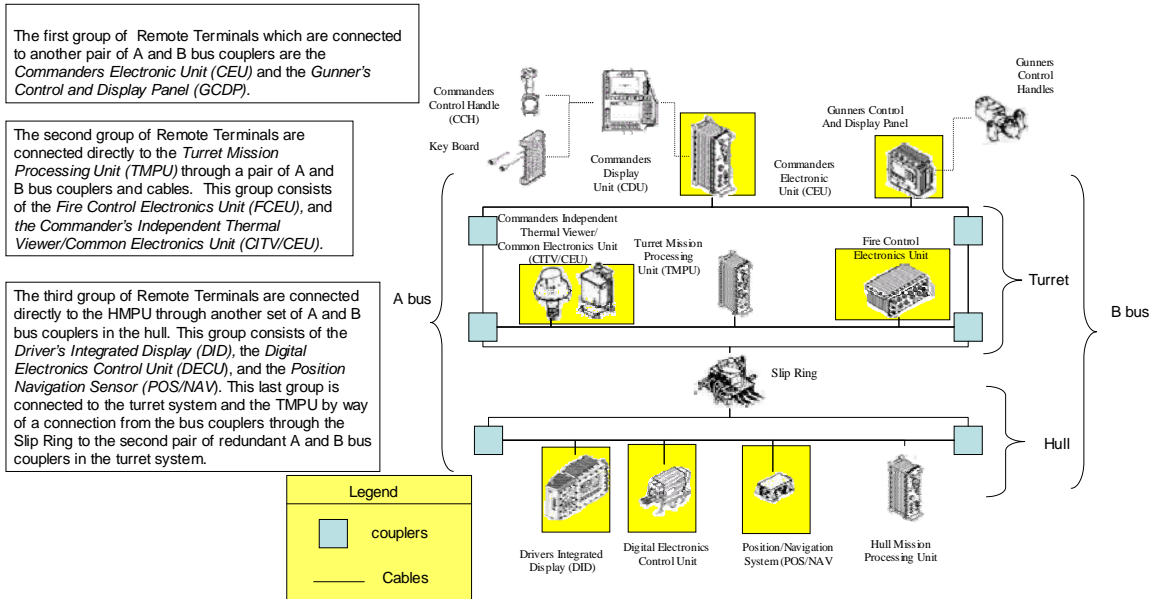


The *Remote Terminals* receive and transmit data on the bus in response to bus controller commands. They are connected to the A and B bus couplers in a specific way, such that, different Remote Terminals are connected to different A and B bus couplers. The couplers in turn are connected to each other on the A and B buses to route all information to the *TMPU* and the *HMPU*.



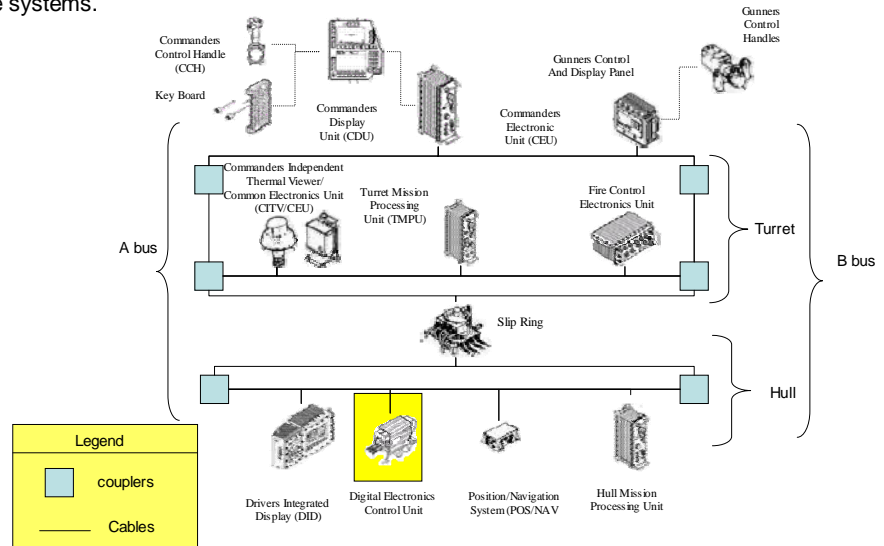
Mechanism of the Remote Terminals: The Remote Terminals are separated into three groups.

Each group of Remote Terminals is connected to a pair of A and B bus couplers.



. The Function of the Digital Electronics Control Unit (DECU):

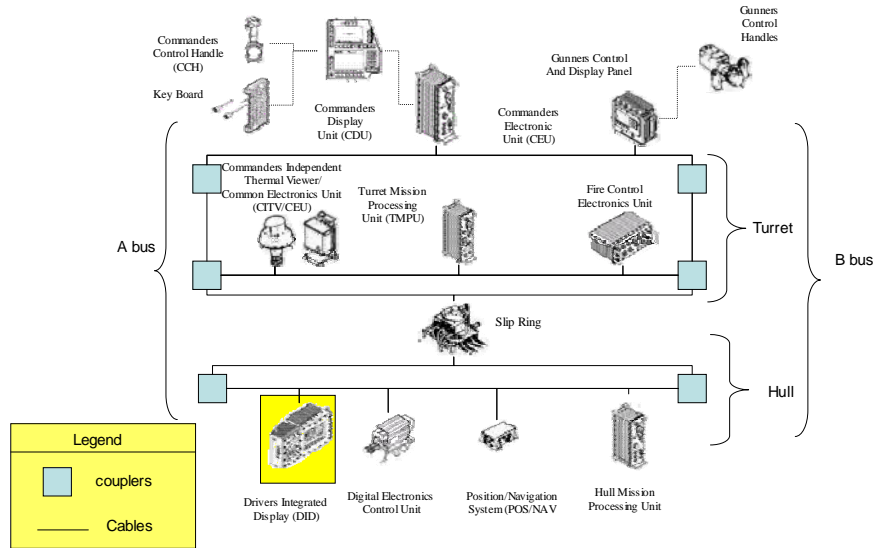
The function of the *Digital Electronics Control Unit (DECU)* is to control certain displays within the *Driver's Integrated Display* through the 1533B bus. The DECU converts analog to digital signals and provides control and monitoring of engine systems.



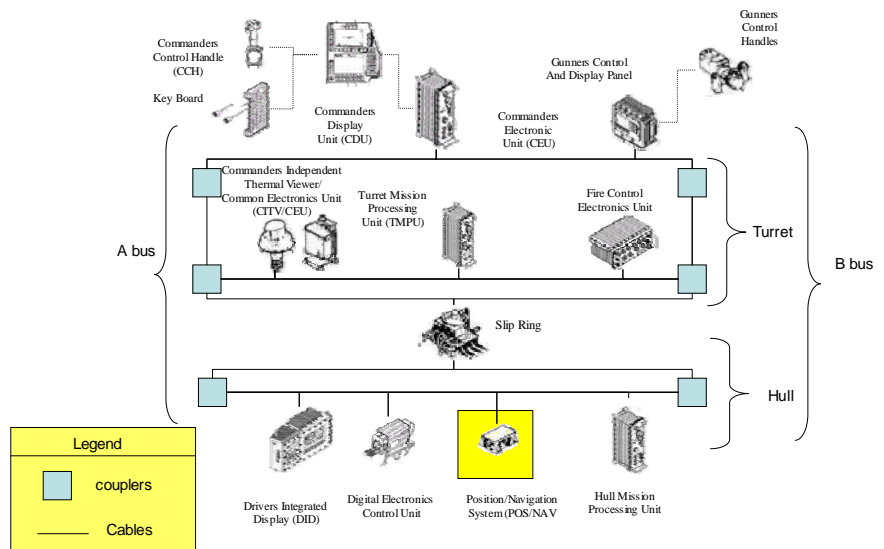
**Generate a sentence using: (DECU), (displays), (digital), (engine systems).**

The Function of the *Driver's Integrated Display (DID)*:

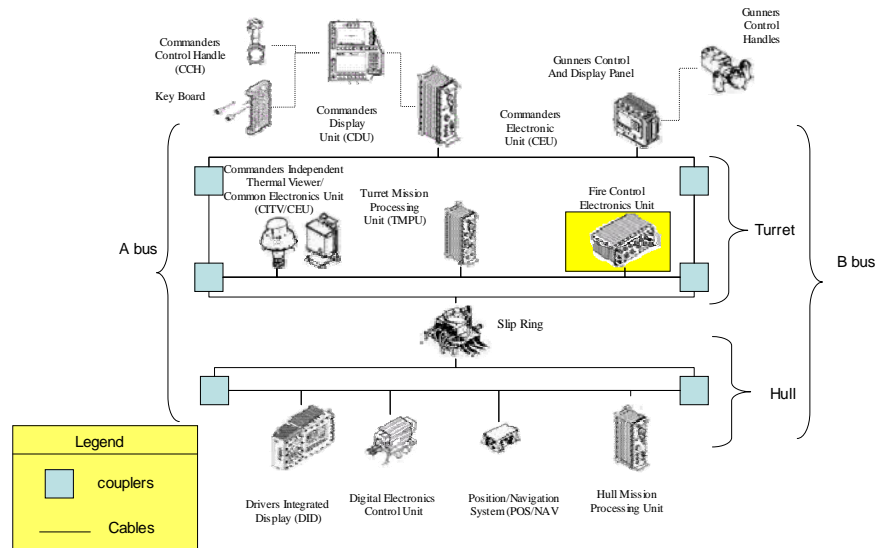
The function of the *DID* is to allow the driver access to all automotive related functions and to select back-up functions of the commander's display unit



The function of the *Position Navigation Sensor (POS/NAV)* is to provide movement and direction data for the commander, driver and the fire control system. It also provides *dynamic cant for the Fire Control System*.



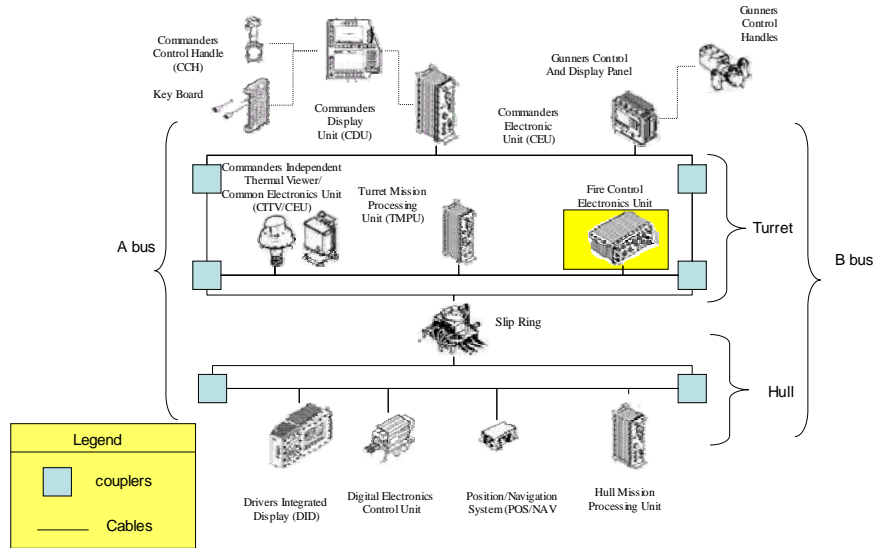
The function of the *Fire Control Electronics Unit (FCEU)*: is to integrate the Gunner's Primary Sight with the *Commander's Independent Thermal Viewer*. This allows the Commander to engage a target from the CITV or from the Gunners Primary Sight.



**Generate a sentence using: (FCEU) and  
(CITV).**

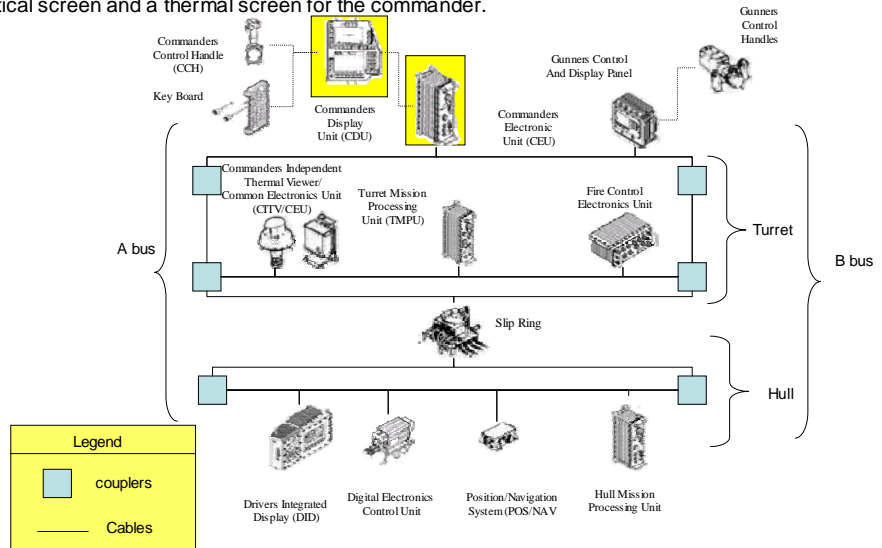
### Remote Terminal Commander's Independent Thermal Viewer/Common Electronics Unit CITV/CEU

The Function of the *Commander's Independent Thermal Viewer/ Common Electronics Unit (CITV/CEU)* is to provide the electronics to give the commander a separate stabilized thermal sight independent of turret movement and the Gunner's Primary Sight. It is independent of the Turret. It can automatically scan or be manually controlled by the commander.



### Remote Terminal Commanders Electronic Unit (CEU)

The *Commanders Electronic Unit CEU* functions to provide the Processing and memory resources for the *Commander's Display Unit* and the command, control and communications functions. It allows for the control of the commander's displays and related databases and serves as the interface to commander controlled inter-vehicular functions like map display server. It also allows interface to common and new tank components and handles passwords, reconfiguration, and radio control through the 1553B bus. It allows operation of vehicle systems and provides a tactical screen and a thermal screen for the commander.



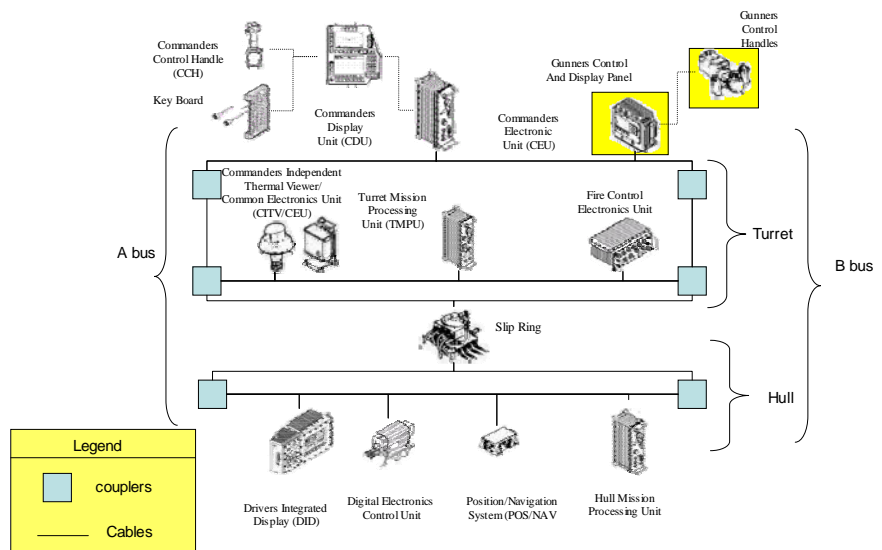
**Generate a sentence using: (processing),  
(memory), and (Commanders Display Unit).**

29

Remote Terminal Gunners Control and Display Panel  
(GCDP)

Group 1

The *Gunners Control and Display Panel (GCDP)* provides the gunner with access to fire control functions and select backup functions for the commanders display unit. The GCDP converts analog signals from the *Gunner's Control Handles* to digital signals to be transmitted on the 1553B bus.





Begin taking test.  
Upon completion of test inform the  
monitor

## **APPENDIX D: PROVIDED QUESTIONING**

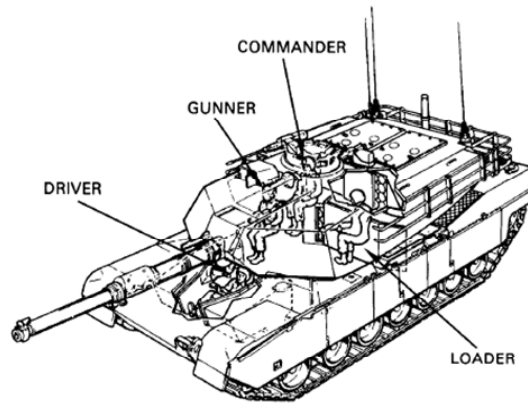
Please read the material at your own pace. During your reading, you will be asked to write answers to questions about curriculum, intended to further your understanding of the material.

Good luck.

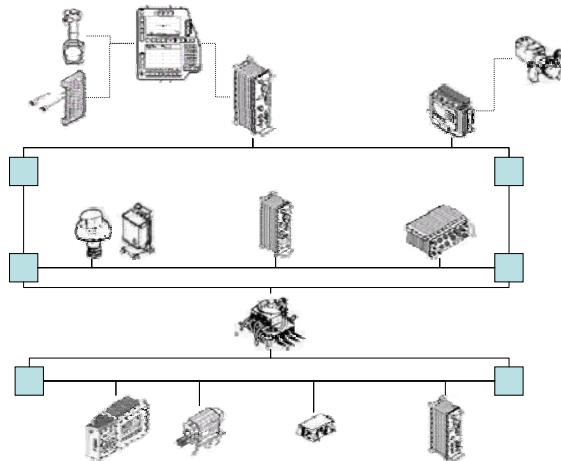
## M1A2 Tank Overview

### Objective: Familiarization with the M1A2 Tank

The M1A2 SEP combat tank uses high speed, maneuverability, and a variety of weapons to accomplish its mission. The tank provides protection from enemy weapons. It has a crew of four individuals. The driver is located in the hull the Gunner, Commander and Loader are Located in the Turret. This training will focus on the 1553B it is the data communications component of the M1A1SEP



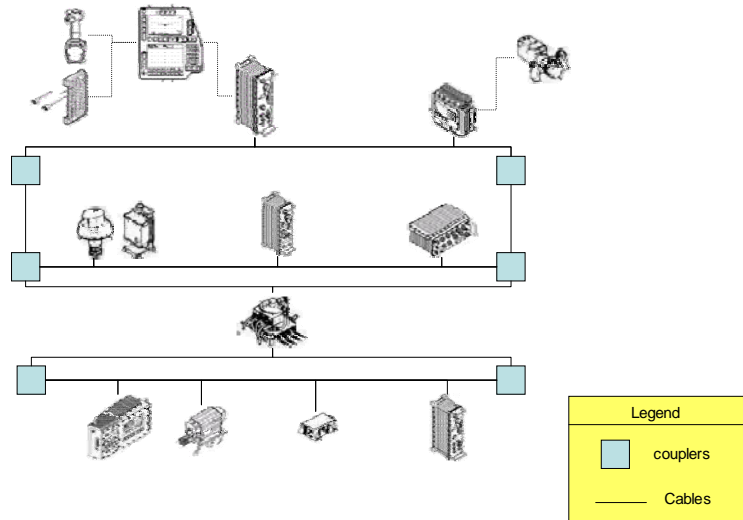
## M1A2 Tank Function



The M1A2 SEP tank system architecture is a set of distributed tank components interconnected to each other by a power distribution network and data distribution network(1553B Bus). This training will only address the 1553 Bus Data Distribution Network.

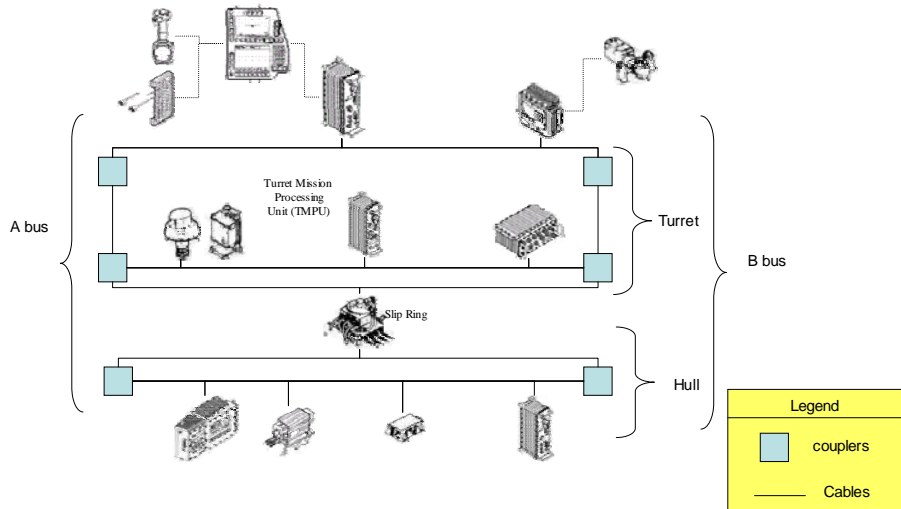
### 1553 Bus Function

Function: The 1553B Data Bus communicates all data messages to *control* and *monitor the functions and applications* of the tank. The diagram has all of the components of the 1553 Data Bus along with the wires and couplers that make up the data bus.



### 1553 Bus Mechanism

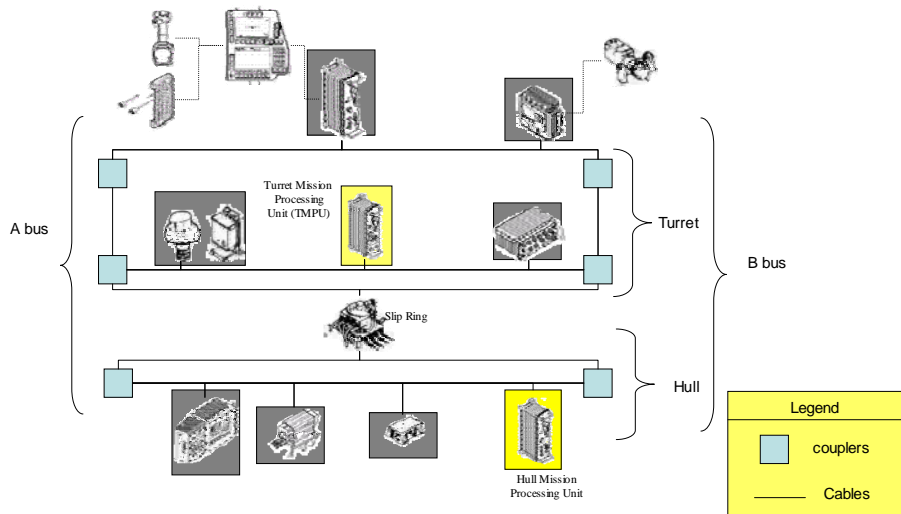
Mechanism: The 1553b data bus consist of a bus controller (also known as the Turret Mission Processor Unit) that *transmits and receives messages* across cables, through the slip ring and couplers. The controller communicates to a monitor and other remote terminals on this bus. This 1553b data bus is *dual redundant* with both an A bus and a B bus. It serves both turret functions and some hull functions.



**What is the TMPU and what functions does it do?**

Function: The A and the B buses insure dual redundancy in the system. They distribute messages to all of *Remote Terminals* and the *Bus Monitor/Hull Mission Processing Unit (HMPU)* from and to the *Turret Mission Processing Unit (TMPU)*. If any bus is damaged the other bus, either the A or B bus which is not damaged, can still transmit information between the *Remote Terminals* and the *Turret Mission Processing Unit (TMPU)*.

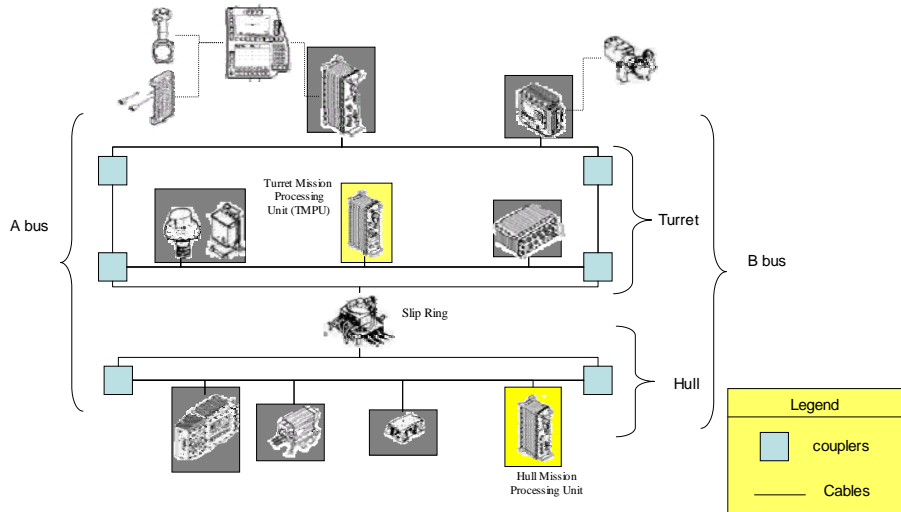
Mechanism: The A bus and B bus consist of a series of cables and couplers that connect the Bus Controller, *Bus Monitor* and *Remote Terminals*.



**What are the advantages of a dual redundant bus system?**

The A and B bus couplers distribute data and messages by bus cables to different Remote Terminals. They connect the *Bus Controller (Turret Mission Processing Unit TMPU)* and *Bus Monitor (Hull Mission Processing Unit HMPU)* to different *Remote Terminals*.

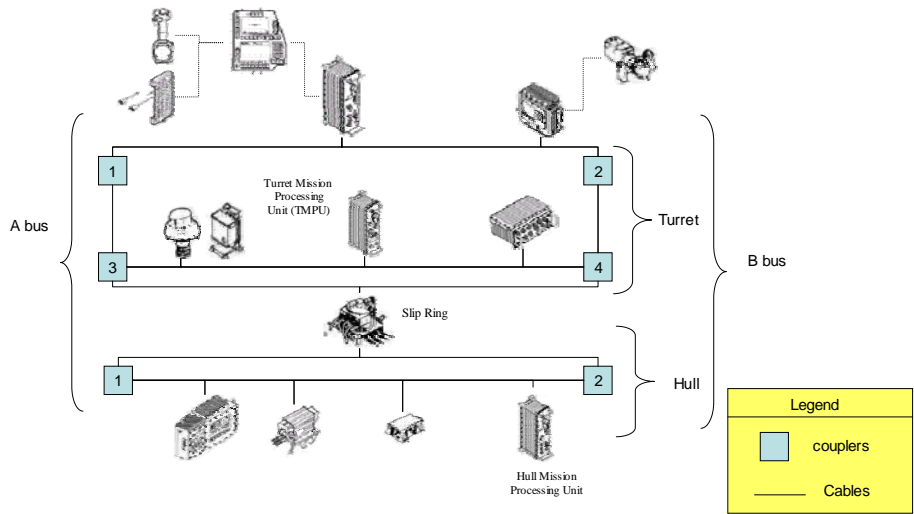
Bus Couplers isolate the A and B Bus to ensure that failure of one of the *Remote Terminal Units*, the *Turret Mission Processing Unit (TMPU)* or the *Hull Mission Processing Unit (HMPU)* will not result in main bus failure. They ACT AS A SURGE Protector protecting other components.



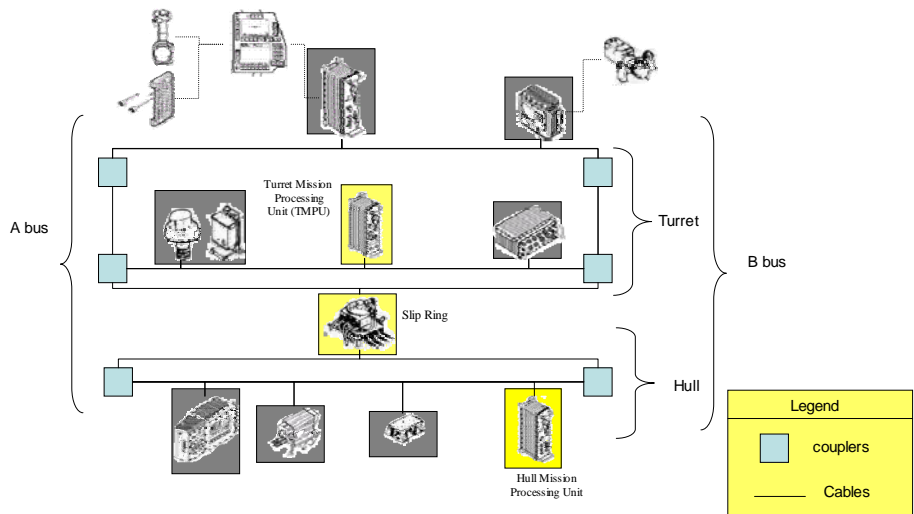
**What is the best feature of the couplers?**



Four bus couplers are located in the *turret* and two are located in the *hull* in different locations. They are connected via cables and the slip ring. The couplers connected by cables routed along different paths to provide redundant capability.

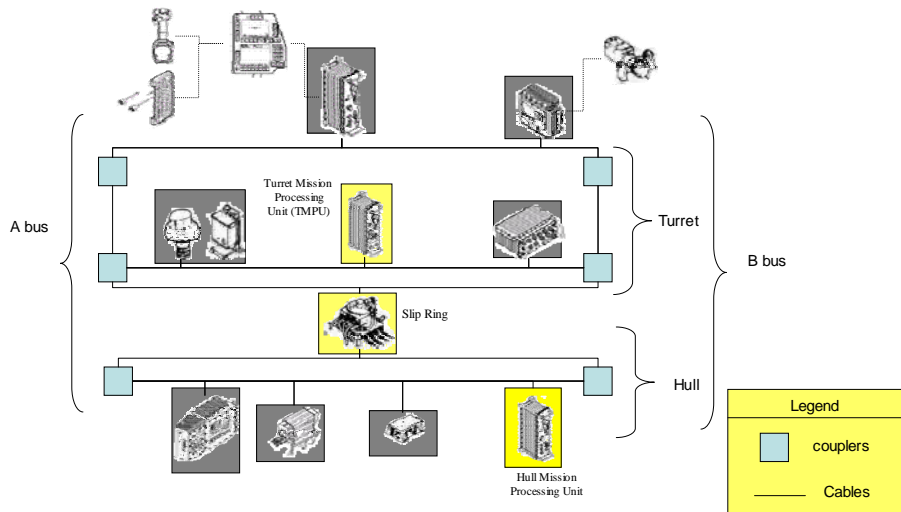


Function: The bus cables are the communication lines between the components of the bus system. They carry all information between components.



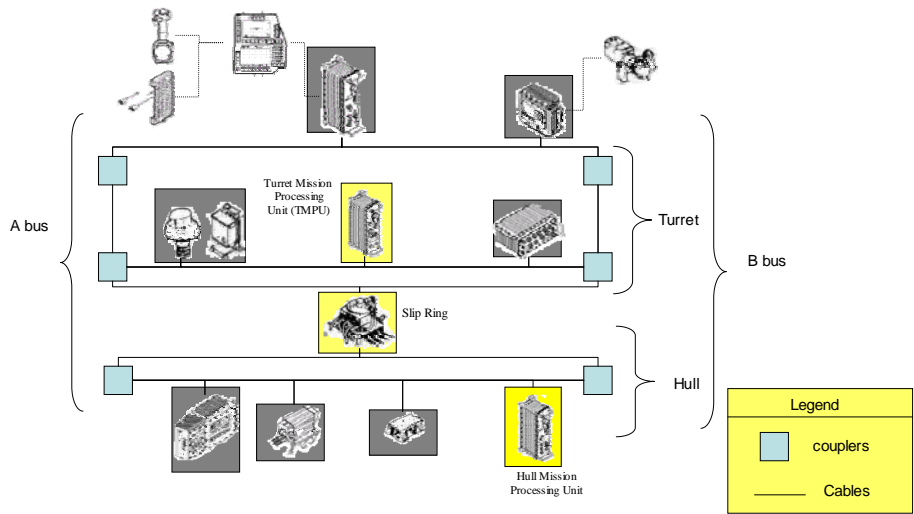
**How is information carried out between  
components?**

Mechanism: *Data bus cables* are a twisted pair of wires, which are shielded and connected to the *Turret Mission Processing Unit (TMPU)*, the *Hull Mission Processing Unit (HMPU)* and other *Remote Terminals*. The cables connect the *TMPU* and the *HMPU* and *Remote Terminals* to the *A bus couplers* and *B bus couplers*. Cables connect to the slip ring so the connection from the *turret* to the *hull* can be made. The cables are routed on different sides of the vehicle to provide redundant capability



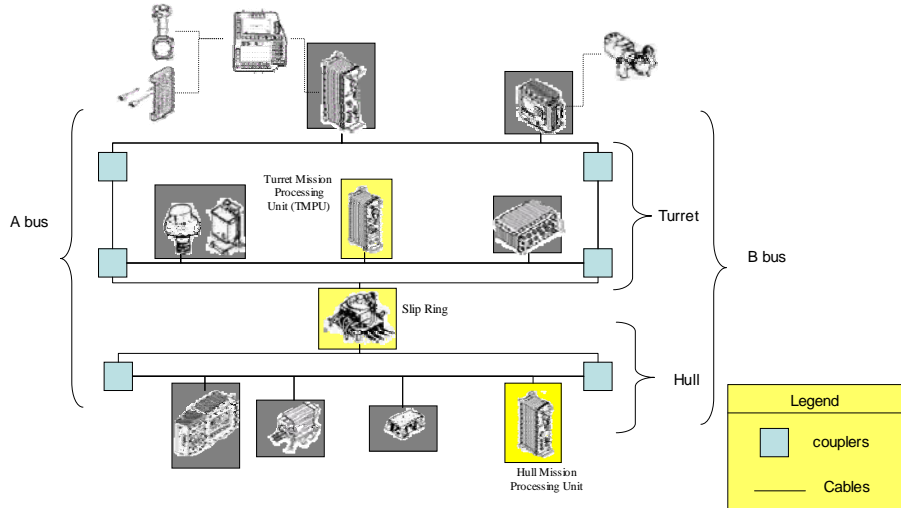
**How are the TMPU and HMPU connected?**

Function: The *Slip Ring* forms the communications link between the two A bus couplers and two B bus couplers which serve the Turret and one A bus coupler and one B bus coupler which serve the Hull.



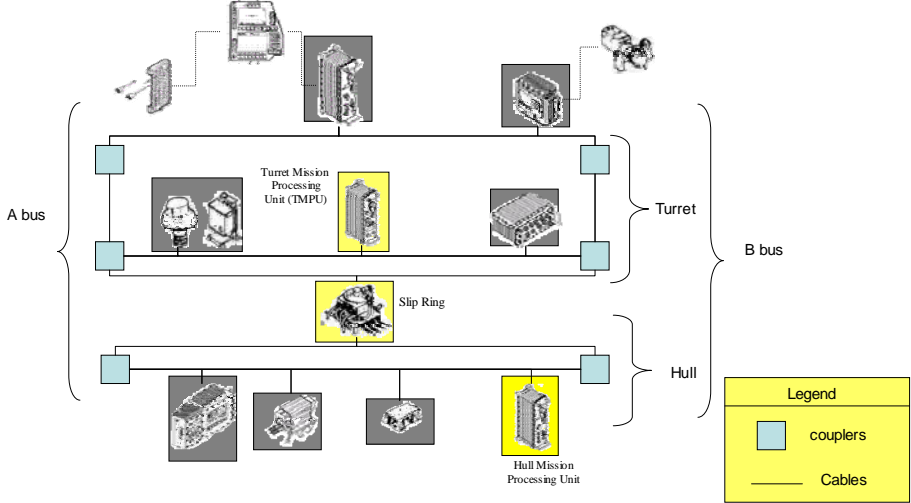
Function: The bus controller is referred to as the *Turret Mission Processing Unit (TMPU)*. It sends and controls the flow of messages across cables through couplers and their cables to remote terminals.

The *TMPU* is also responsible for conducting all system diagnostic checks and for calculating ballistic solutions for the tank under normal operations. These diagnostic and ballistic functions make the TMPU like another remote terminal.

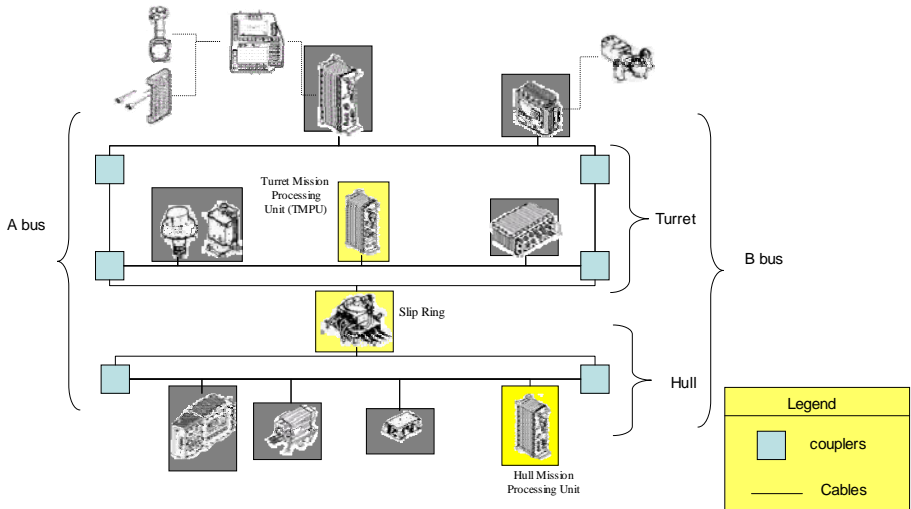


**What are the “other” functions of the TMPU?**

Mechanism: The *TMPU* communicates to *Remote Terminals* through redundant A and B buses. The *TMPU* consists of many computer processors which *control and manage* information transmission throughout the tank Turret systems and the Hull systems by way of cables and couplers. The *TMPU* talks to the *Bus Monitor* referred to as the *Hull Mission Processing Unit (HMPU)* through the A bus and B bus via the slip ring. The *TMPU* by way of the A and B buses can talk to all *Remote Terminals*, which perform various functions. The *TMPU* can control the talk between any two *Remote Terminals* by way of the A and B buses. Only one terminal can talk to one terminal at a time and the sequence in which any two terminals can talk is established by a fixed priority by the bus controller.

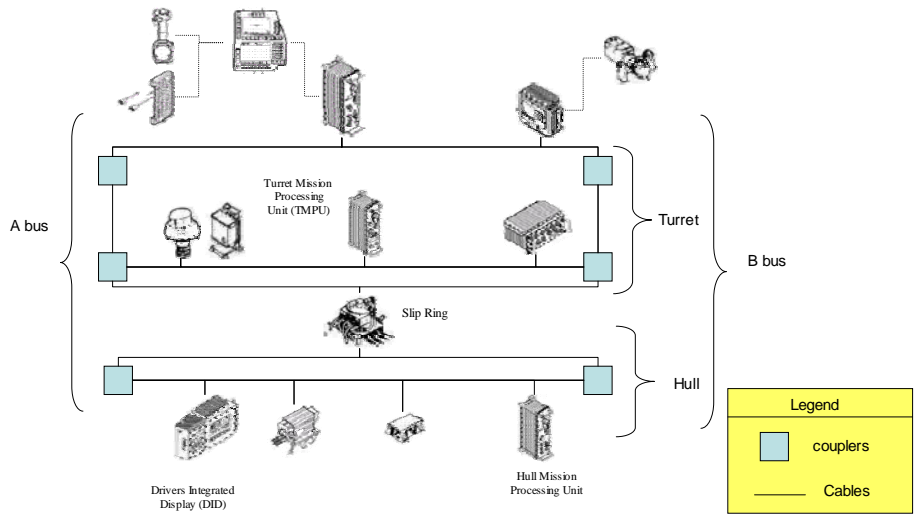


One of the *TMPU's* Remote Terminal functions is calculating ballistic solutions for the Fire Control System. It does this by storing and managing *critical data* such as Boresight data, plumb and sync., scan limits and rate, all drift data, ammo type, all zero data, Commander's Independent Thermal Viewer adjustments, and Sensor inputs for crosswind, cant, lead, ammo temperature and battle-sight range which is then used to *compute solutions for the fire control system employing the processors and the software of the TMPU.*



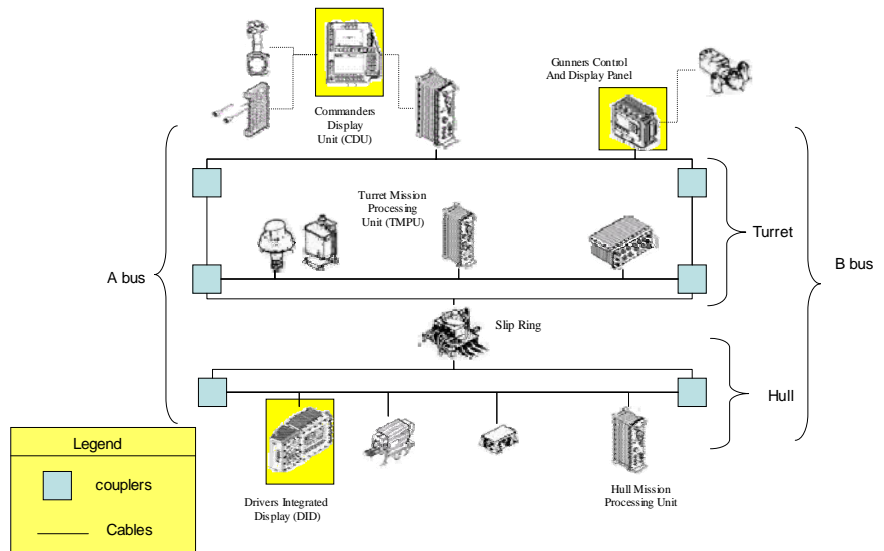
15 Remote Terminal Function of the Turret Mission Processing Unit: Diagnostic Group 1

Another Remote Terminal-like function of the Turret Mission Processing Unit (TMPU) is *diagnosing system components*. There are three different types of test, the *Self-Test (ST)*, the *Built in Test (BIT)* and the *Fault Isolation Test (FIT)*.



16 Remote Terminal Mechanism of the Turret Mission Processing Unit: Self Test Group 1

*Self-Test* is designed to run in the background without interfering with normal operations. If a fault is detected by the *Self-Test*, a caution or warning message is displayed in one of three locations; the *Commander's Display Unit*, the *Gunner's Control Display Panel* or the *Driver's Integrated Display*. This is an automatic test and runs constantly in the background.

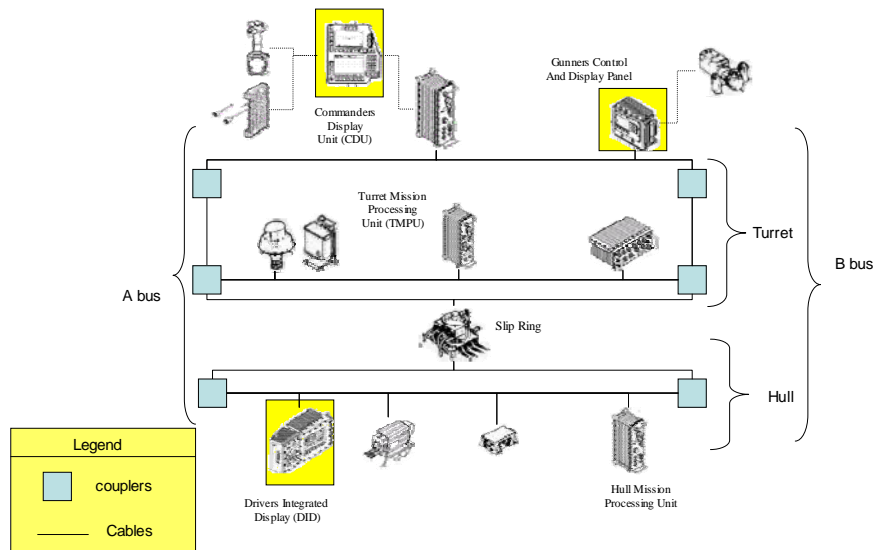


**How is the self-test run?**



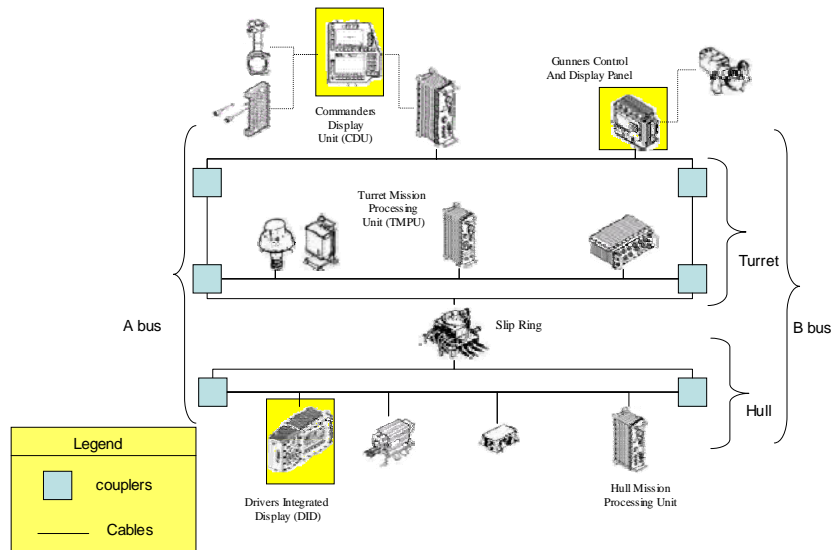
17 Remote Terminal Mechanism of the Turret Mission Processing Unit: Built In Test Group 1

The *Built in Test* is designed to provide extensive and comprehensive test coverage of the component in which the *BIT* is embedded. The *BIT* is an intrusive test which requires components to be shut down. When a fault is detected by *BIT* in its related component, it will display a NOGO message on the *Commander's Display Unit*, the *Gunner's Control Display Panel* or the *Driver's Integrated Display* to alert the crew or mechanic that a fault has occurred



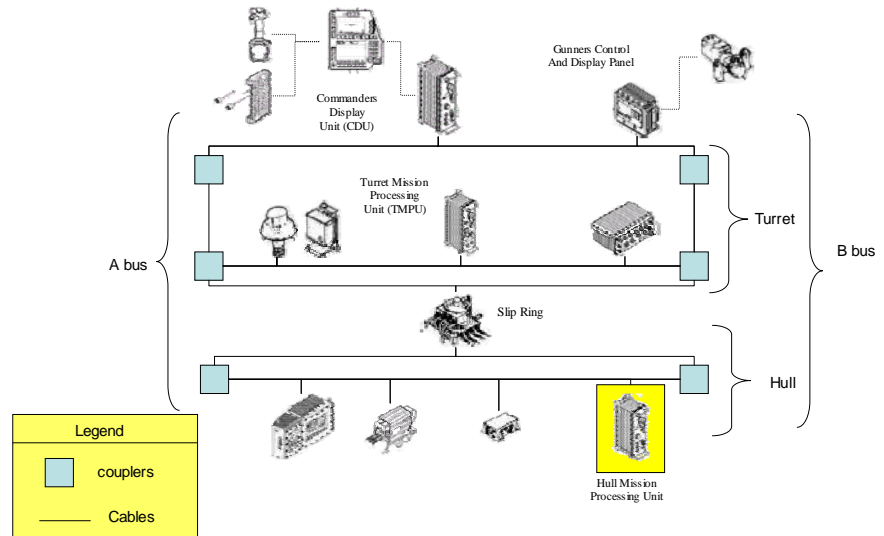
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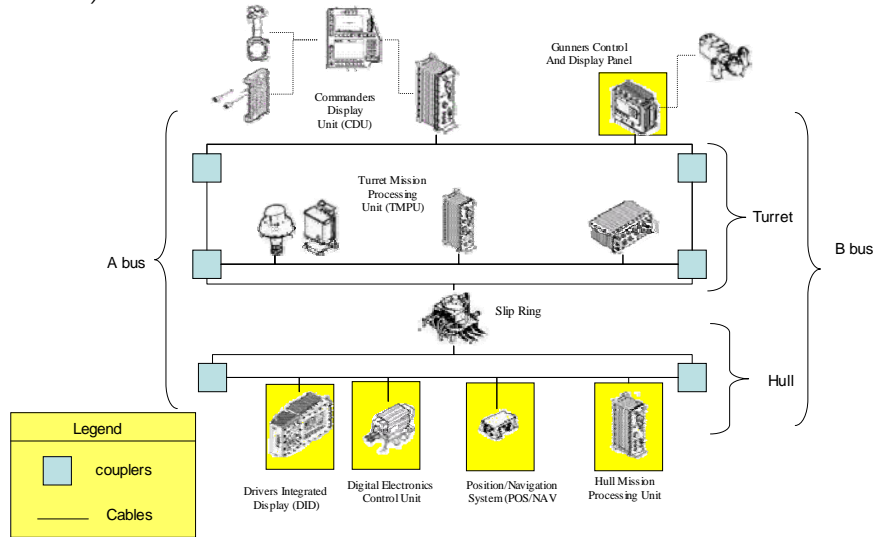
**What conclusions can you make about the  
fault isolation test?**

Function: The *Bus Monitor* or the *Hull Mission Processing Unit (HMPU)* is the *backup* for the *Bus Controller* or *Turret Mission Processing Unit (TMPU)*. If the *TMPU* fails, the *HMPU* can carry out all of the *Bus Controller functions except for the use of Global Positioning System information*. Global Positioning System information used for position information is fed directly to the *TMPU* and cannot be accessed by the *HMPU*. *This is the only function which is not dual redundant in the 1553B bus system*. The *HMPU*, like the *TMPU* can send messages across cables through couplers and their cables to remote terminals in the Hull and through cables, couplers and the slip ring to the remote terminals in the turret.

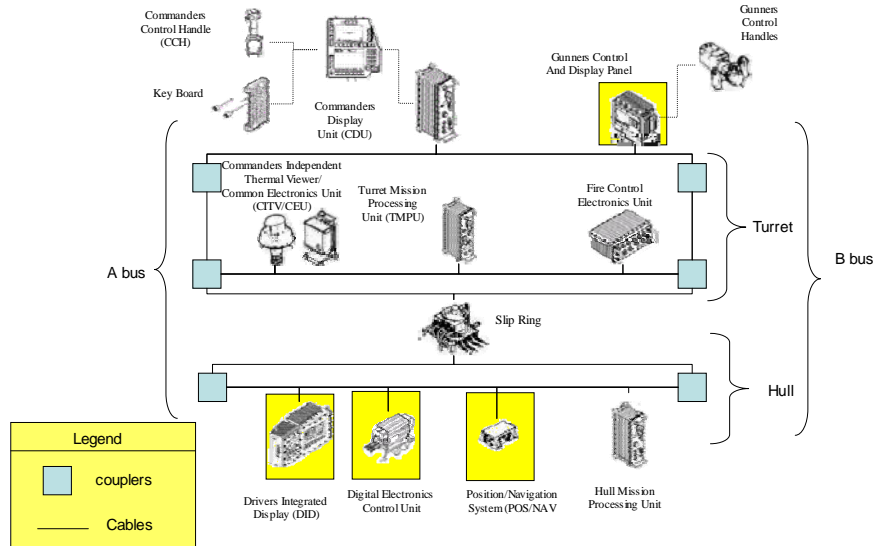


**How the HMPU is related to the TMPU that you read about earlier?**

Mechanism: The *Hull Mission Processing Unit (HMPU)* is also connected to two couplers one on the A bus and one on the B bus in the same way as the *Turret Mission Processing Unit (TMPU)*. This makes up six couplers in all with the addition of the two A and two B bus couplers of the Turret system. Three on the A bus and three on the B bus. The other Remote terminals which are connected along with the HMPU to these two couplers are: The *Driver's Integrated Display Unit (DID)*, the *Digital Electronics Control Unit (DECU)* and the *Position Navigation (POS/NAV) sensor*.

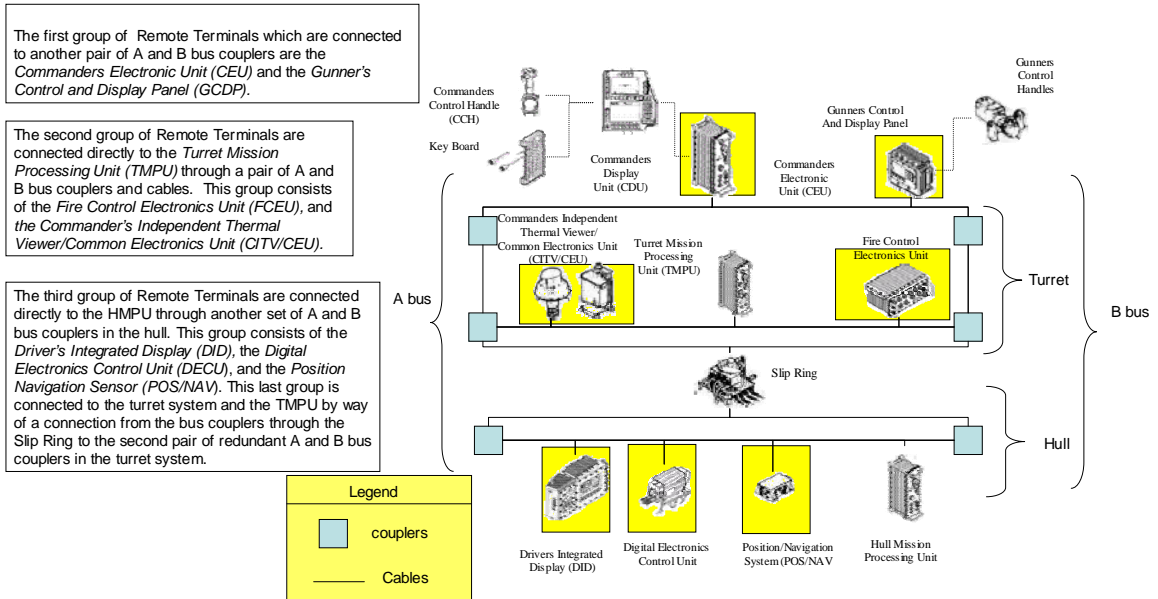


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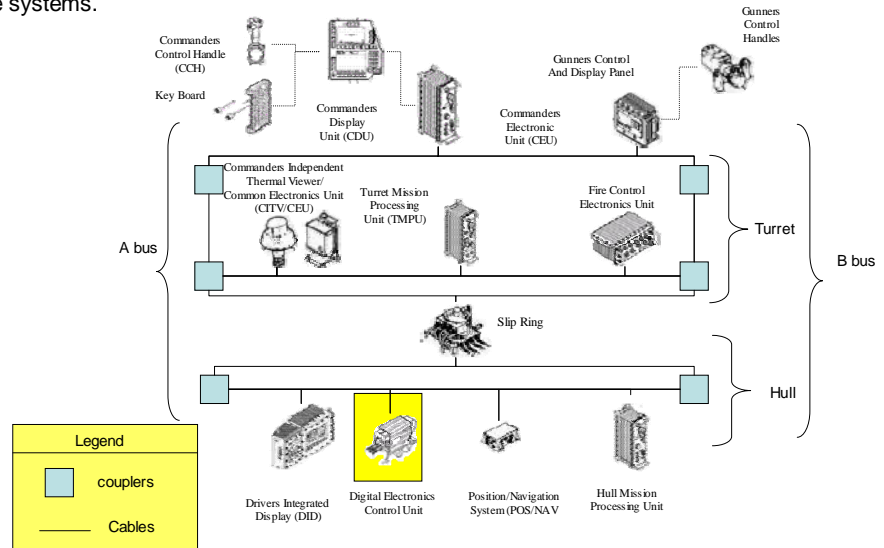
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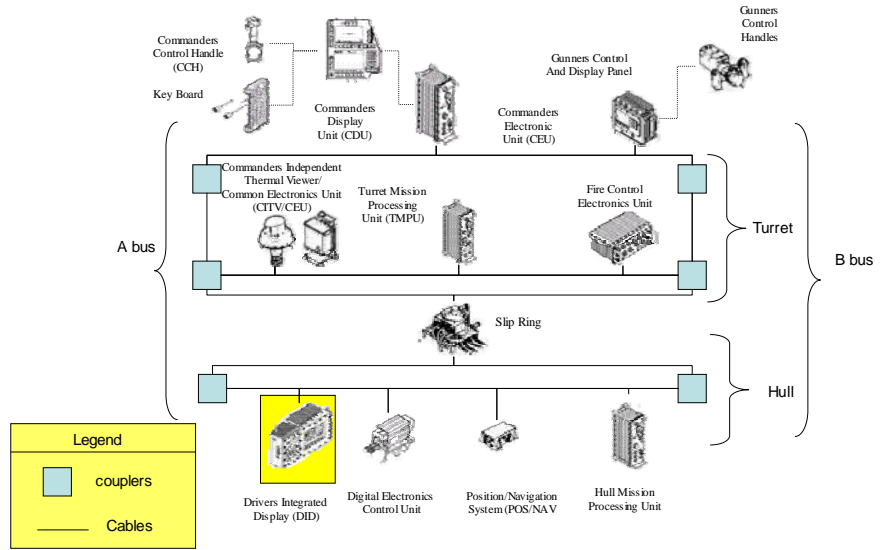
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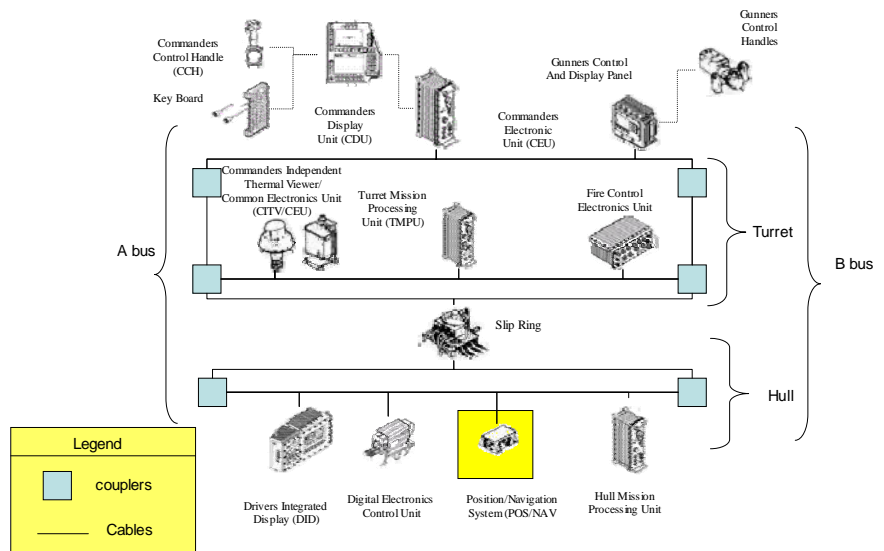
**Explain the functions of the DECU?**

The Function of the *Driver's Integrated Display (DID)*:

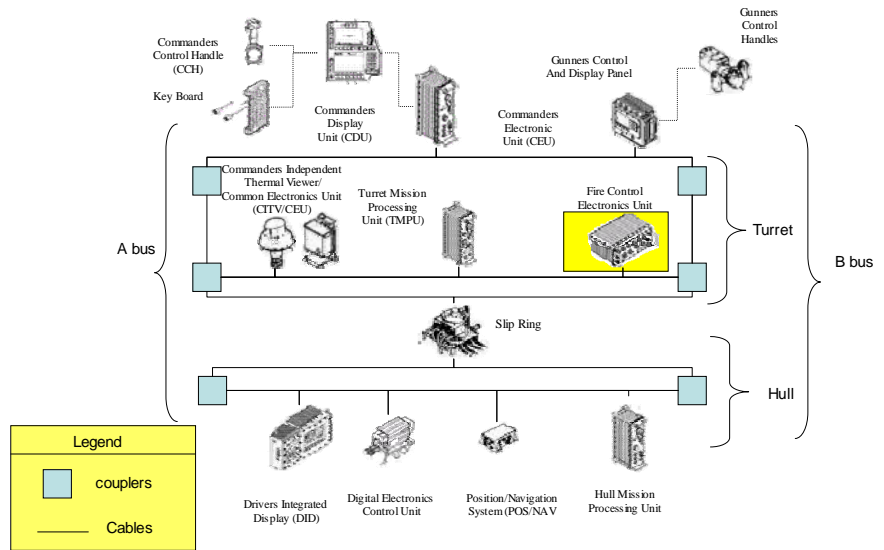
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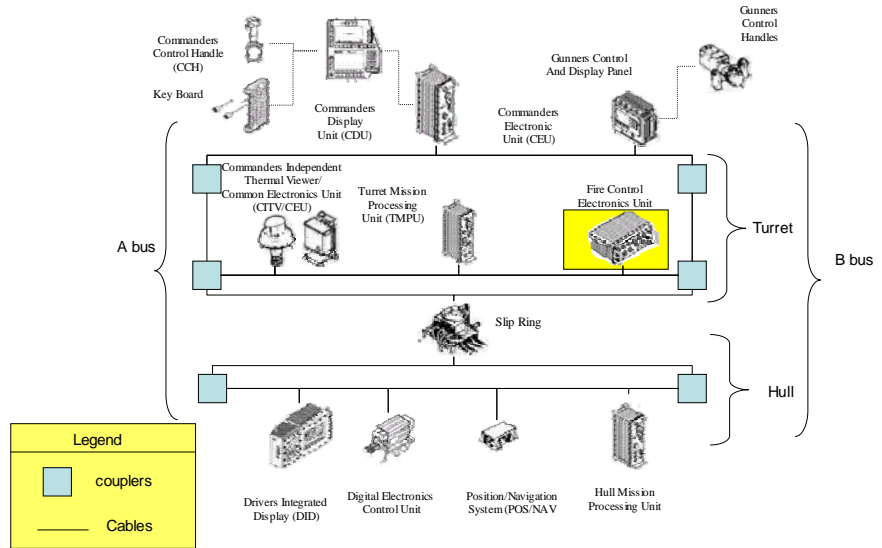


**What does the FCEU do?**



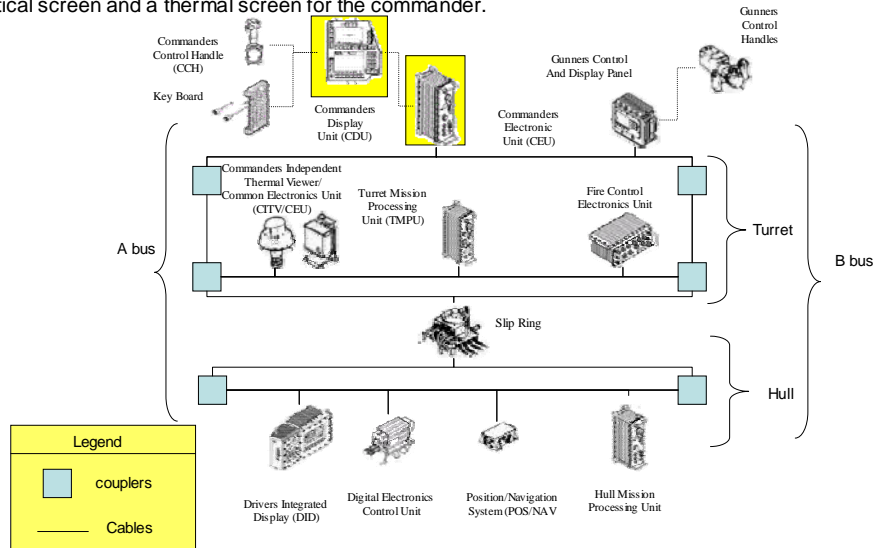
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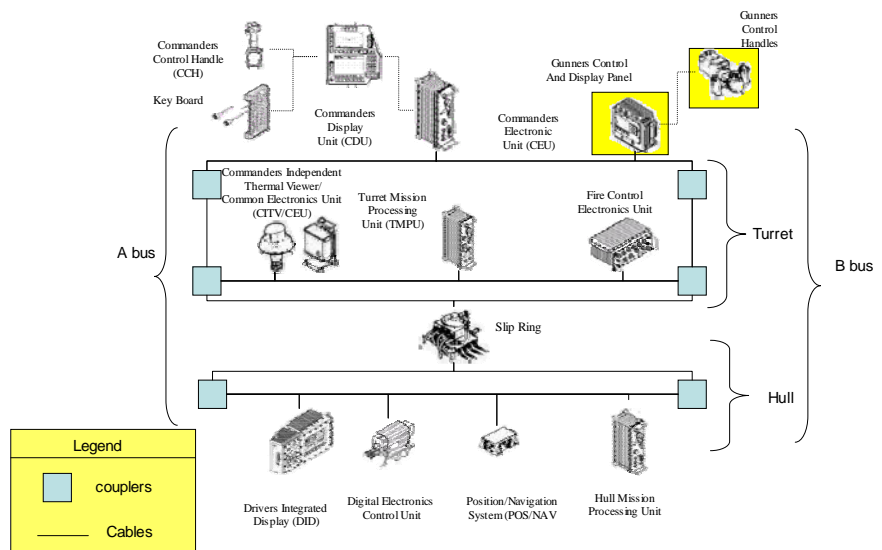
# What is the importance of the CEU?

29

## Remote Terminal Gunners Control and Display Panel (GCDP)

Group 1

The *Gunnery Control and Display Panel (GCDP)* provides the gunner with access to fire control functions and select backup functions for the commanders display unit. The GCDP converts analog signals from the *Gunner's Control Handles* to digital signals to be transmitted on the 1553B bus.



Begin taking test.  
Upon completion of test inform the  
monitor

## **APPENDIX E: SELF-GENERATED QUESTIONING**

Please read the material at your own pace. During your reading, you will be prompted to pose questions about the material and answer them. Consider the following question as guide to generate your own questions:

Any thoughts about that sentence?

Could you explain the concept of the idea discussed in this sentence?

What's going on here?

How?

Why?

What do I understand from this passage?

Anything else you can tell me about it?

What is the main idea of...?

What makes you think this way?

How would you use...to...?

What is a new example of...?

Does this make sense so far?

What is the difference between... and...?

What conclusions can you make about...?

How does... affect...?

What are the strength and weaknesses of...?

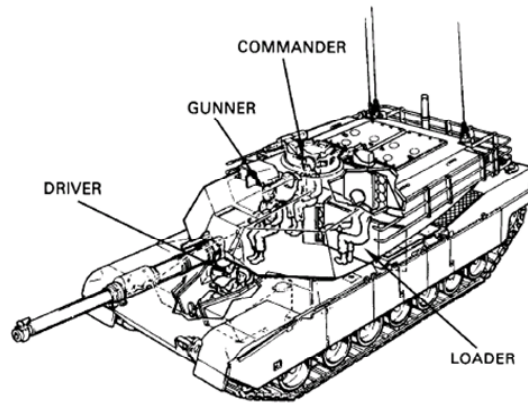
What is the best... and why?

How is... related to... that we studied earlier?

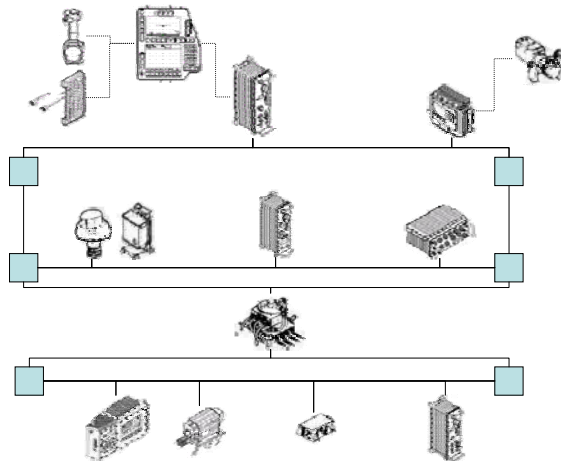
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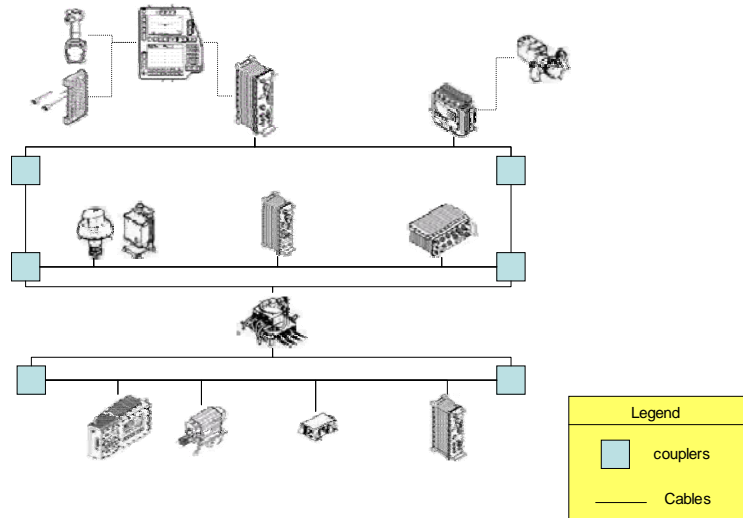
## M1A2 Tank Function



The M1A2 SEP tank system architecture is a set of distributed tank components interconnected to each other by a power distribution network and data distribution network(1553B Bus). This training will only address the 1553 Bus Data Distribution Network.

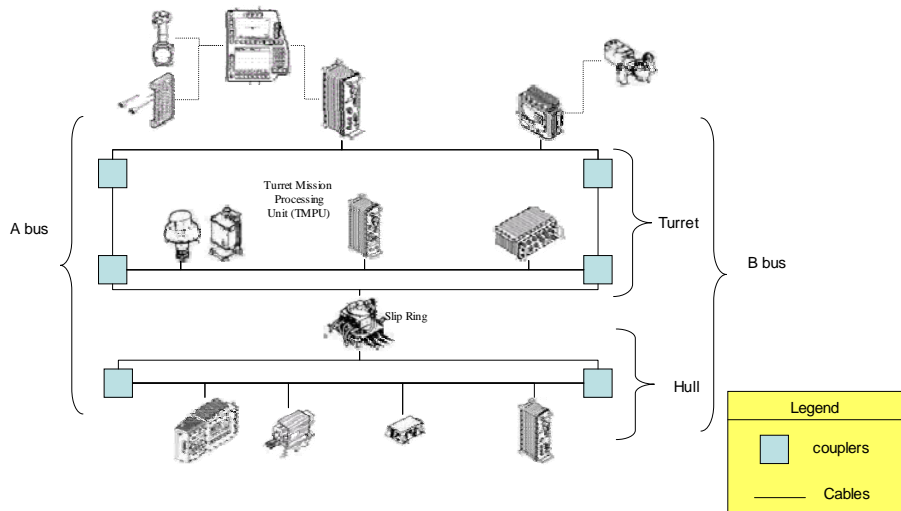
## 1553 Bus Function

Function: The 1553B Data Bus communicates all data messages to *control* and *monitor the functions and applications* of the tank. The diagram has all of the components of the 1553 Data Bus along with the wires and couplers that make up the data bus.



## 1553 Bus Mechanism

Mechanism: The 1553b data bus consist of a bus controller (also known as the Turret Mission Processor Unit) that *transmits and receives messages* across cables, through the slip ring and couplers. The controller communicates to a monitor and other remote terminals on this bus. This 1553b data bus is *dual redundant* with both an A bus and a B bus. It serves both turret functions and some hull functions.

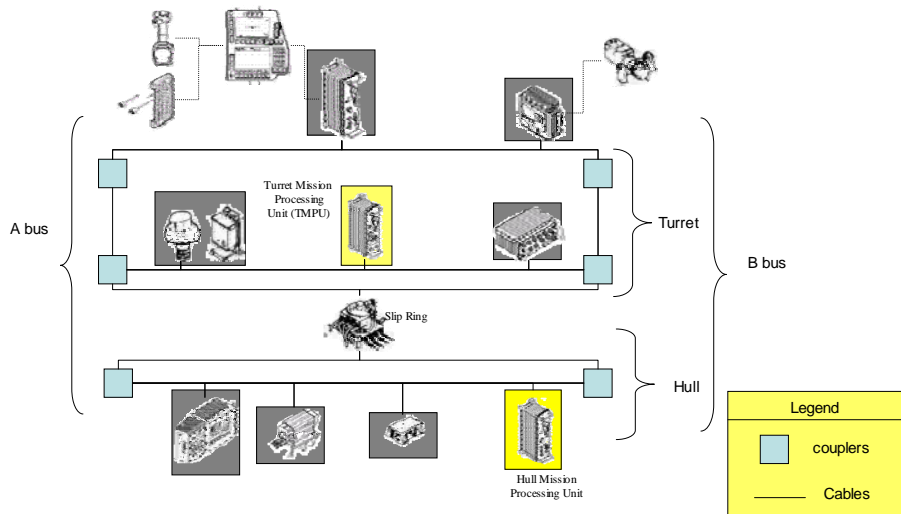


**Ask a question about the turret mission  
processor unit and answer it.**



Function: The A and the B buses insure dual redundancy in the system. They distribute messages to all of *Remote Terminals* and the *Bus Monitor/Hull Mission Processing Unit (HMPU)* from and to the *Turret Mission Processing Unit (TMPU)*. If any bus is damaged the other bus, either the A or B bus which is not damaged, can still transmit information between the *Remote Terminals* and the *Turret Mission Processing Unit (TMPU)*.

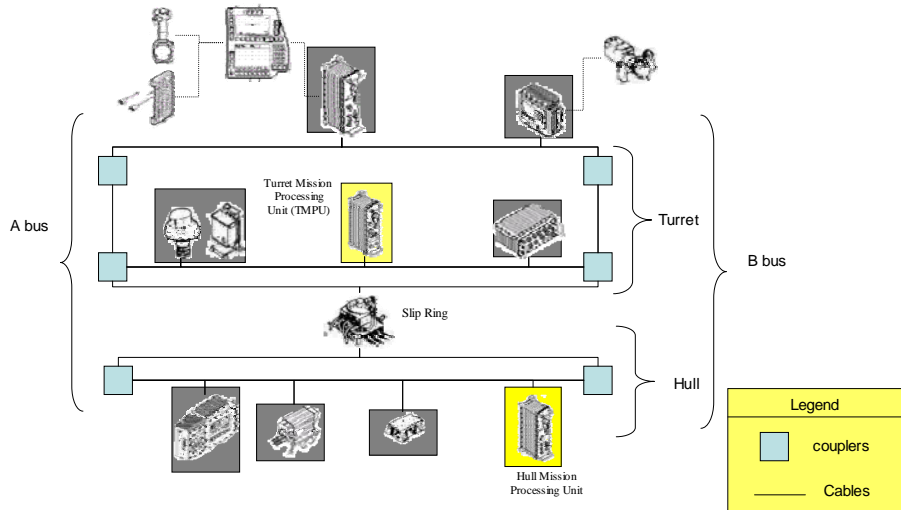
Mechanism: The A bus and B bus consist of a series of cables and couplers that connect the Bus Controller, *Bus Monitor* and *Remote Terminals*.



**Ask a question about the dual redundant feature and answer it.**

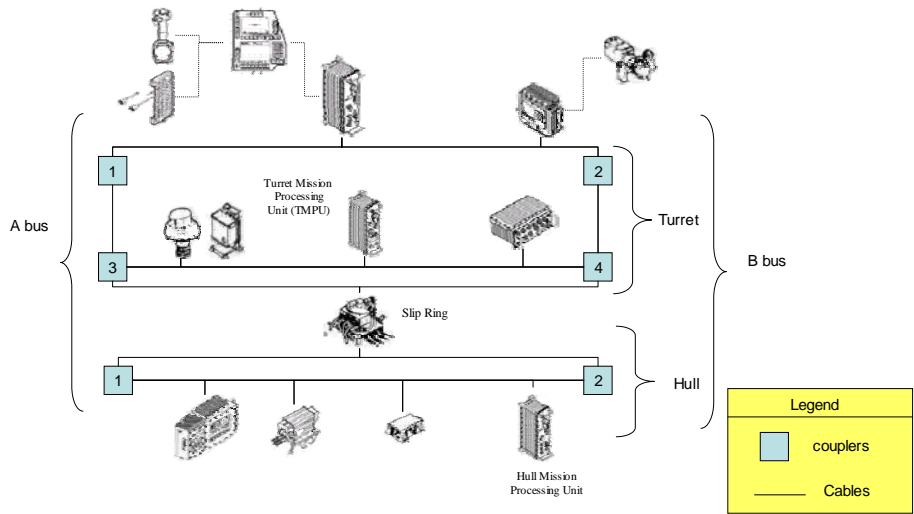
The A and B bus couplers distribute data and messages by bus cables to different Remote Terminals. They connect the *Bus Controller (Turret Mission Processing Unit TMPU)* and *Bus Monitor (Hull Mission Processing Unit HMPU)* to different *Remote Terminals*.

Bus Couplers isolate the A and B Bus to ensure that failure of one of the *Remote Terminal Units*, the *Turret Mission Processing Unit (TMPU)* or the *Hull Mission Processing Unit (HMPU)* will not result in main bus failure. They ACT AS A SURGE Protector protecting other components.

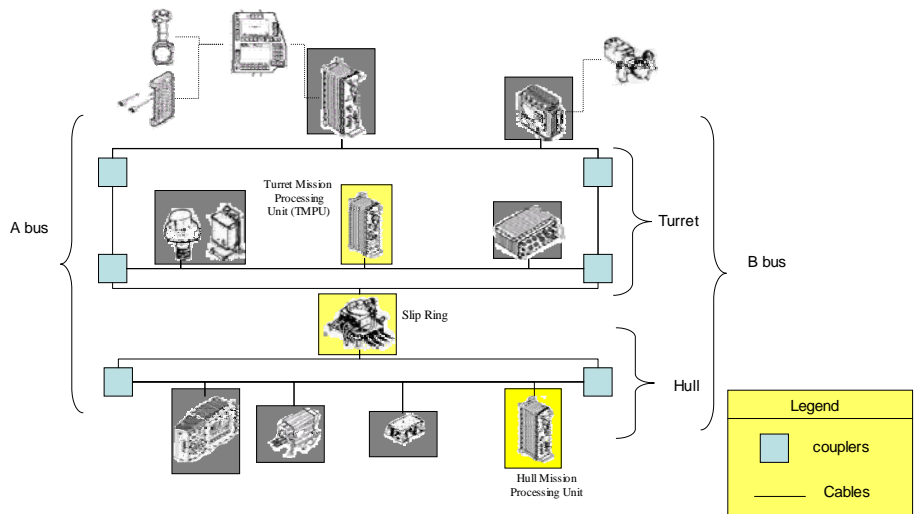


**Ask a question about the bus couplers and answer it.**

Four bus couplers are located in the *turret* and two are located in the *hull* in different locations. They are connected via cables and the slip ring. The couplers connected by cables routed along different paths to provide redundant capability.

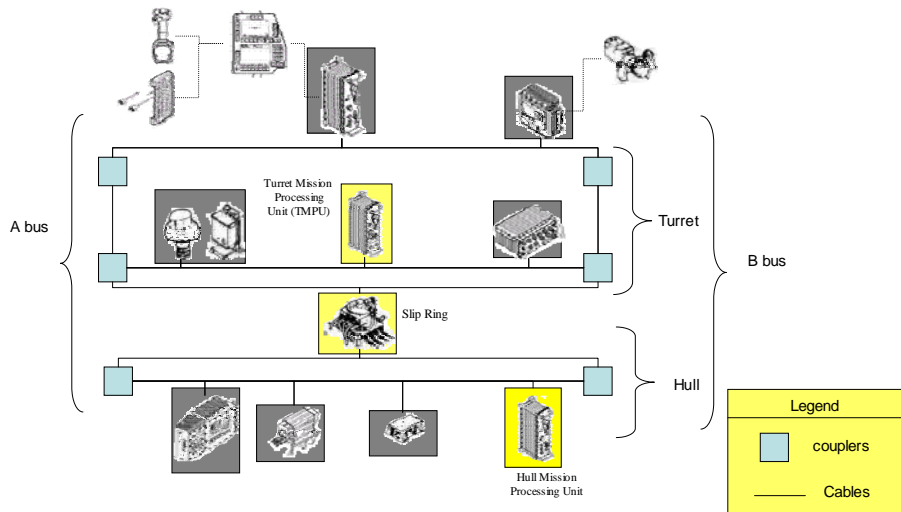


Function: The bus cables are the communication lines between the components of the bus system. They carry all information between components.



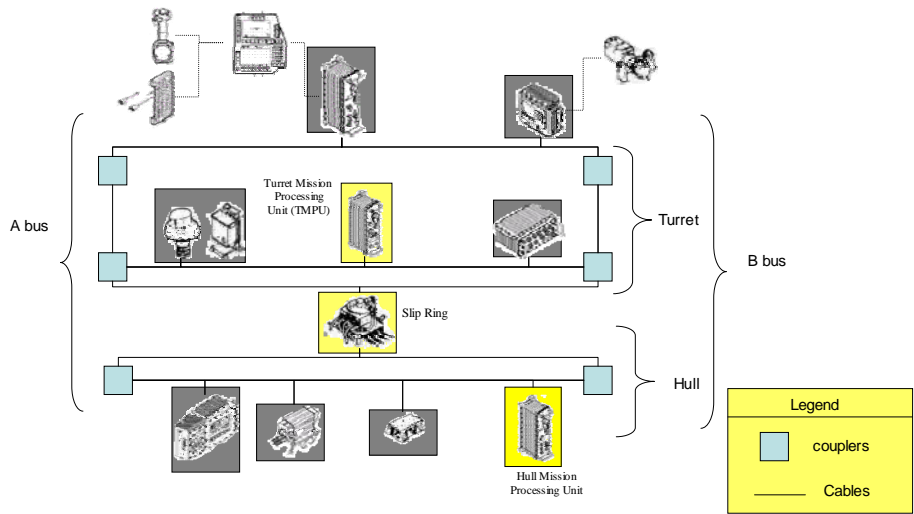
**Ask a question about the “information flow”  
and answer it.**

Mechanism: *Data bus cables* are a twisted pair of wires, which are shielded and connected to the *Turret Mission Processing Unit (TMPU)*, the *Hull Mission Processing Unit (HMPU)* and other *Remote Terminals*. The cables connect the *TMPU* and the *HMPU* and *Remote Terminals* to the *A bus couplers* and *B bus couplers*. Cables connect to the slip ring so the connection from the *turret* to the *hull* can be made. The cables are routed on different sides of the vehicle to provide redundant capability



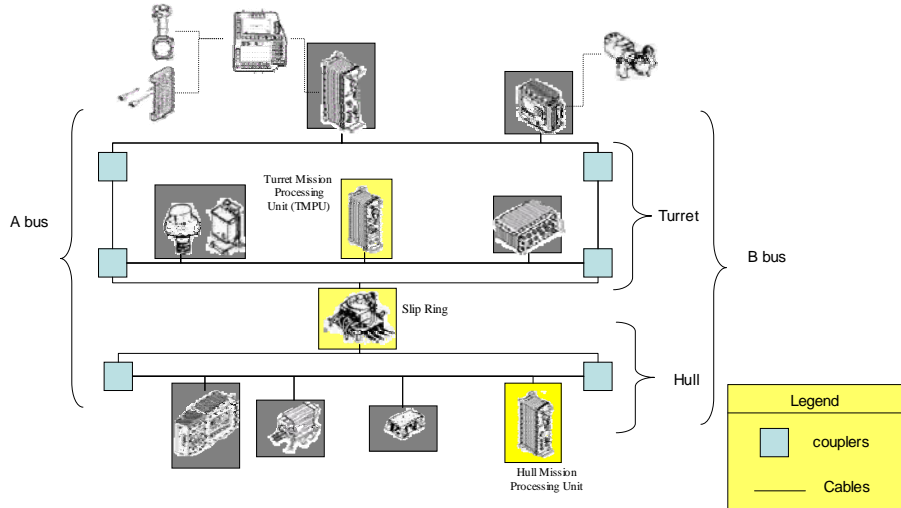
**Ask a question about the connections and answer it.**

Function: The *Slip Ring* forms the communications link between the two A bus couplers and two B bus couplers which serve the Turret and one A bus coupler and one B bus coupler which serve the Hull.



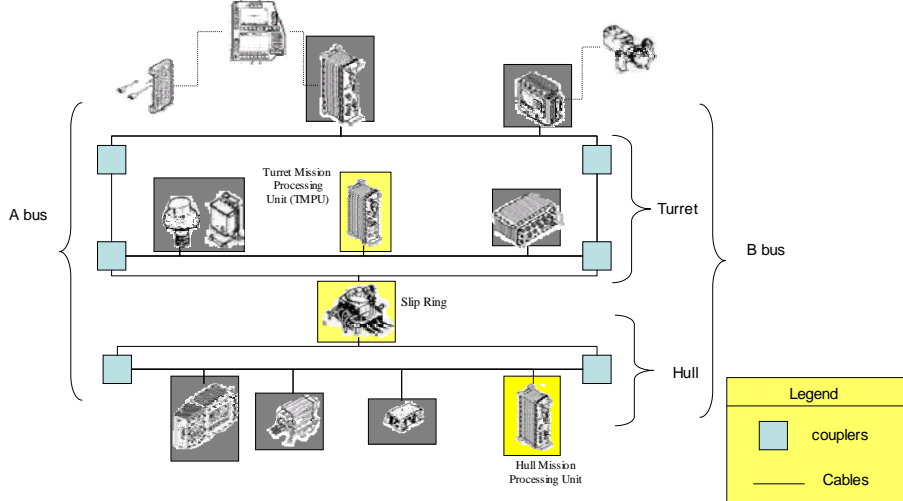
Function: The bus controller is referred to as the *Turret Mission Processing Unit (TMPU)*. It sends and controls the flow of messages across cables through couplers and their cables to remote terminals.

The *TMPU* is also responsible for conducting all system diagnostic checks and for calculating ballistic solutions for the tank under normal operations. These diagnostic and ballistic functions make the TMPU like another remote terminal.

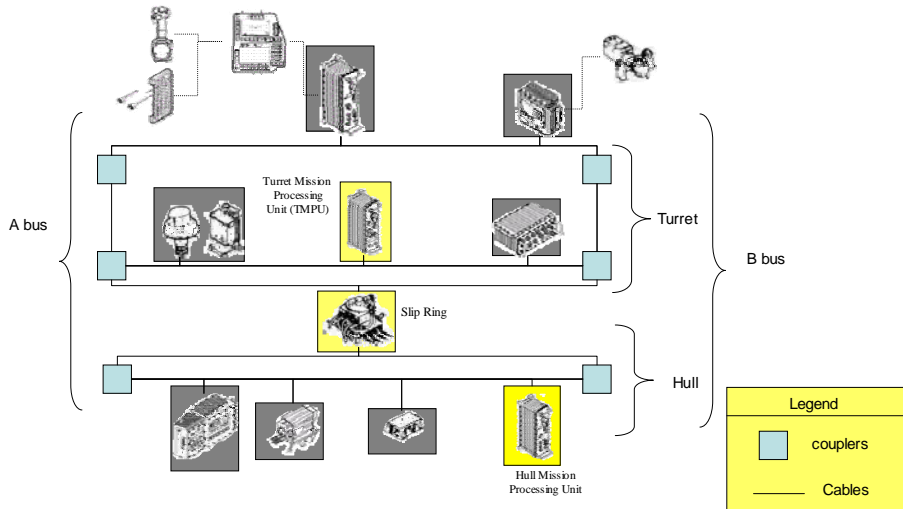


**Ask a question the TMPU functions and answer it.**

Mechanism: The *TMPU* communicates to *Remote Terminals* through redundant A and B buses. The *TMPU* consists of many computer processors which *control and manage* information transmission throughout the tank Turret systems and the Hull systems by way of cables and couplers. The *TMPU* talks to the *Bus Monitor* referred to as the *Hull Mission Processing Unit (HMPU)* through the A bus and B bus via the slip ring. The *TMPU* by way of the A and B buses can talk to all *Remote Terminals*, which perform various functions. The *TMPU* can control the talk between any two *Remote Terminals* by way of the A and B buses. Only one terminal can talk to one terminal at a time and the sequence in which any two terminals can talk is established by a fixed priority by the bus controller.



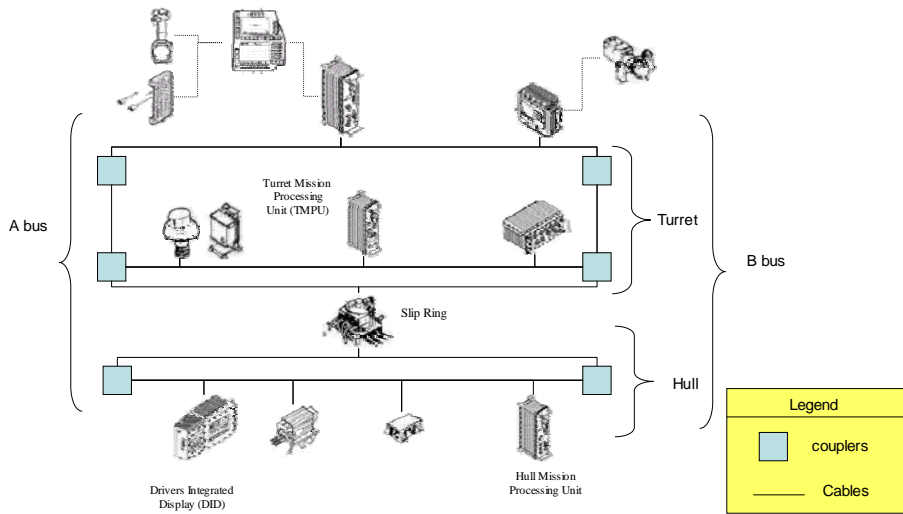
One of the *TMPU's* Remote Terminal functions is calculating ballistic solutions for the Fire Control System. It does this by storing and managing *critical data* such as Boresight data, plumb and sync., scan limits and rate, all drift data, ammo type, all zero data, Commander's Independent Thermal Viewer adjustments, and Sensor inputs for crosswind, cant, lead, ammo temperature and battle-sight range which is then used to *compute solutions for the fire control system employing the processors and the software of the TMPU.*





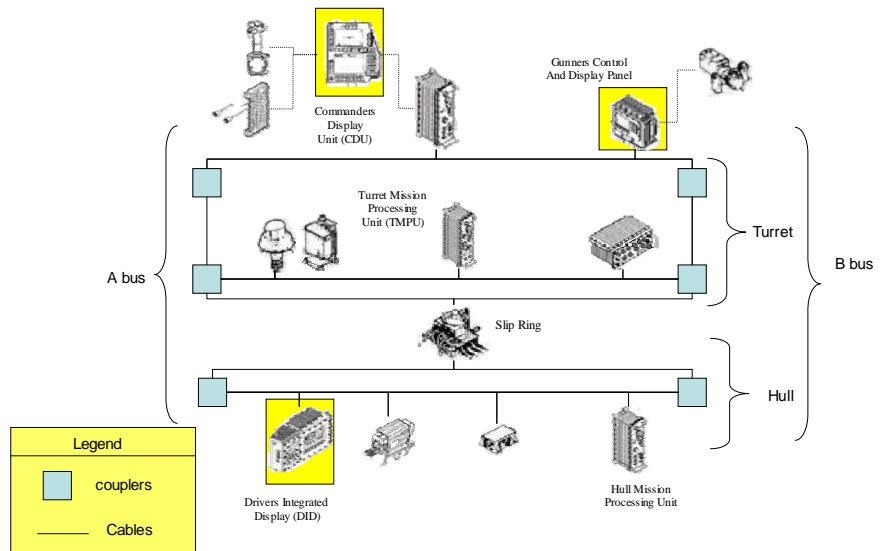
15 Remote Terminal Function of the Turret Mission Processing Unit: Diagnostic Group 1

Another Remote Terminal-like function of the Turret Mission Processing Unit (TMPU) is *diagnosing system components*. There are three different types of test, the *Self-Test (ST)*, the *Built in Test (BIT)* and the *Fault Isolation Test (FIT)*.



16 Remote Terminal Mechanism of the Turret Mission Processing Unit: Self Test Group 1

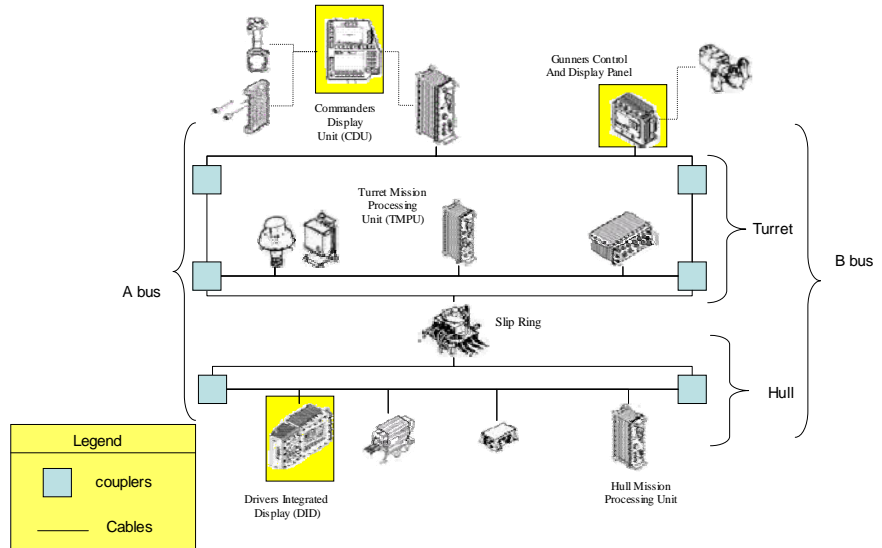
*Self-Test* is designed to run in the background without interfering with normal operations. If a fault is detected by the *Self-Test*, a caution or warning message is displayed in one of three locations; the *Commander's Display Unit*, the *Gunner's Control Display Panel* or the *Driver's Integrated Display*. This is an automatic test and runs constantly in the background.



**Ask a question about the self test and answer  
it.**

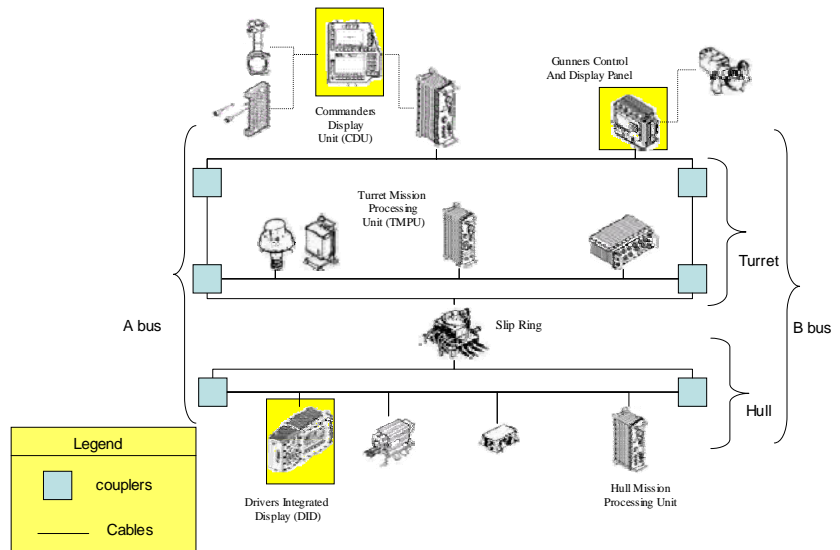
17 Remote Terminal Mechanism of the Turret Mission Processing Unit: Built In Test Group 1

The *Built in Test* is designed to provide extensive and comprehensive test coverage of the component in which the *BIT* is embedded. The *BIT* is an intrusive test which requires components to be shut down. When a fault is detected by *BIT* in its related component, it will display a NOGO message on the *Commander's Display Unit*, the *Gunner's Control Display Panel* or the *Driver's Integrated Display* to alert the crew or mechanic that a fault has occurred



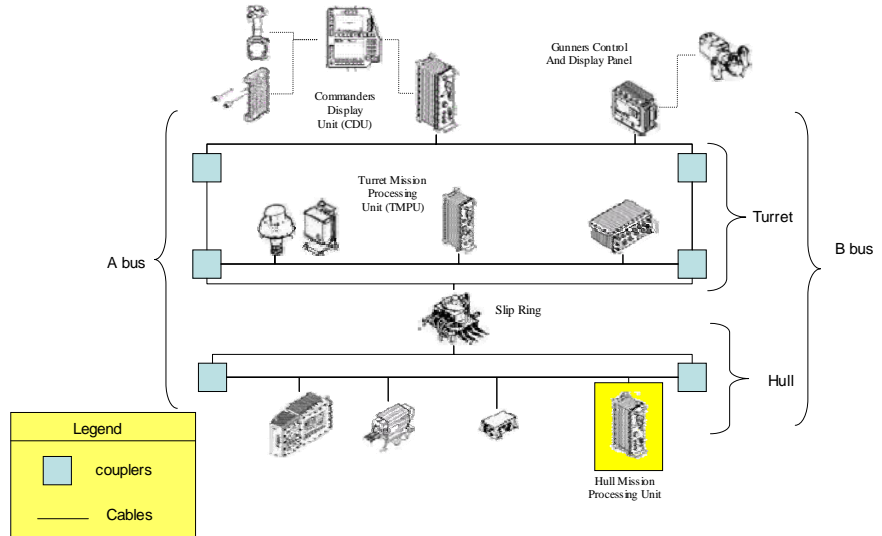
18 Remote Terminal Mechanism of the Turret Mission Processing Unit: Fault Isolation Test Group 1

The *Fault Isolation Test (FIT)* is designed to pinpoint a fault within a group of detected failures or support further testing of the system beyond the capabilities of the *Self-Test* or the *Built-In test*. Maintenance personnel will conduct *FIT* from the *Commander's Display Unit*, the *Gunner's Control Display Panel* or the *Driver's Integrated Display* depending upon the type of fault detected.



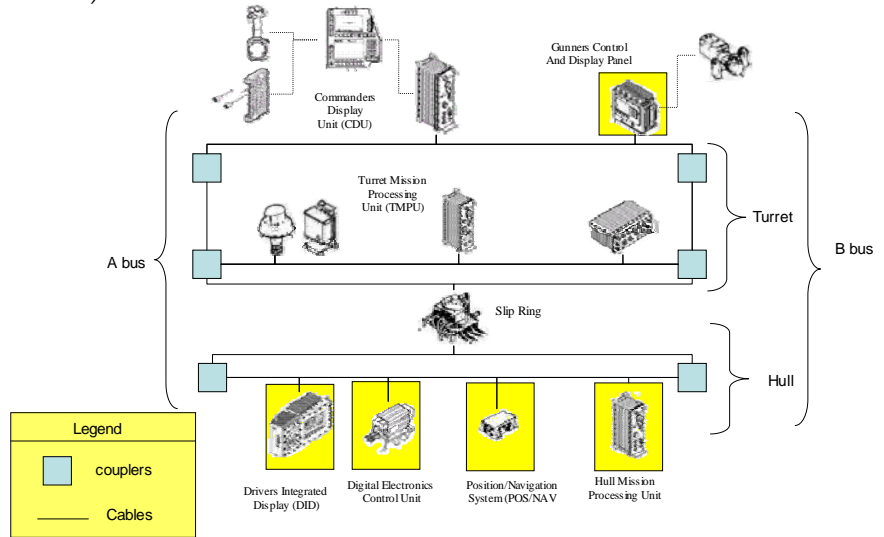
**Ask a question about the fault isolation test  
and answer it.**

Function: The *Bus Monitor* or the *Hull Mission Processing Unit (HMPU)* is the *backup* for the *Bus Controller* or *Turret Mission Processing Unit (TMPU)*. If the *TMPU* fails, the *HMPU* can carry out all of the *Bus Controller functions except for the use of Global Positioning System information*. Global Positioning System information used for position information is fed directly to the *TMPU* and cannot be accessed by the *HMPU*. *This is the only function which is not dual redundant in the 1553B bus system*. The *HMPU*, like the *TMPU* can send messages across cables through couplers and their cables to remote terminals in the Hull and through cables, couplers and the slip ring to the remote terminals in the turret.

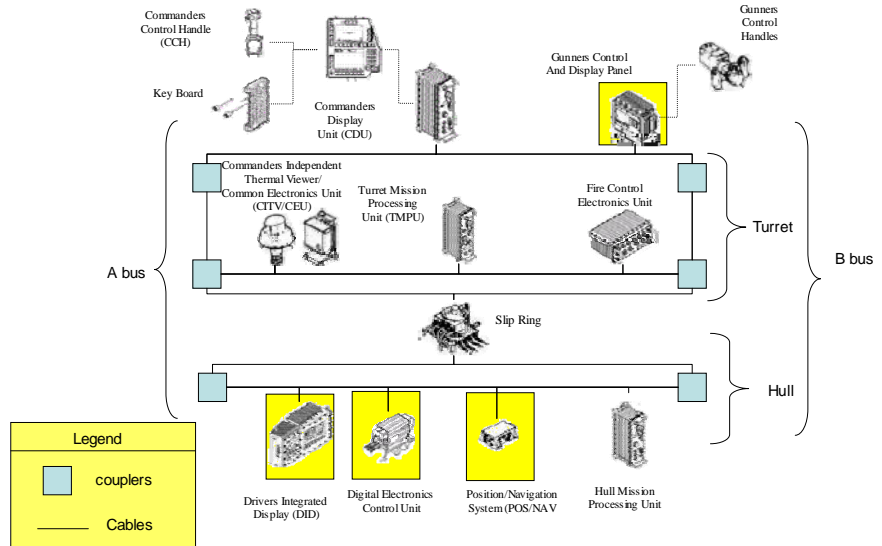


**Ask a question about the HMPU and answer it.**

Mechanism: The *Hull Mission Processing Unit (HMPU)* is also connected to two couplers one on the A bus and one on the B bus in the same way as the *Turret Mission Processing Unit (TMPU)*. This makes up six couplers in all with the addition of the two A and two B bus couplers of the Turret system. Three on the A bus and three on the B bus. The other Remote terminals which are connected along with the HMPU to these two couplers are: The *Driver's Integrated Display Unit (DID)*, the *Digital Electronics Control Unit (DECU)* and the *Position Navigation (POS/NAV) sensor*.

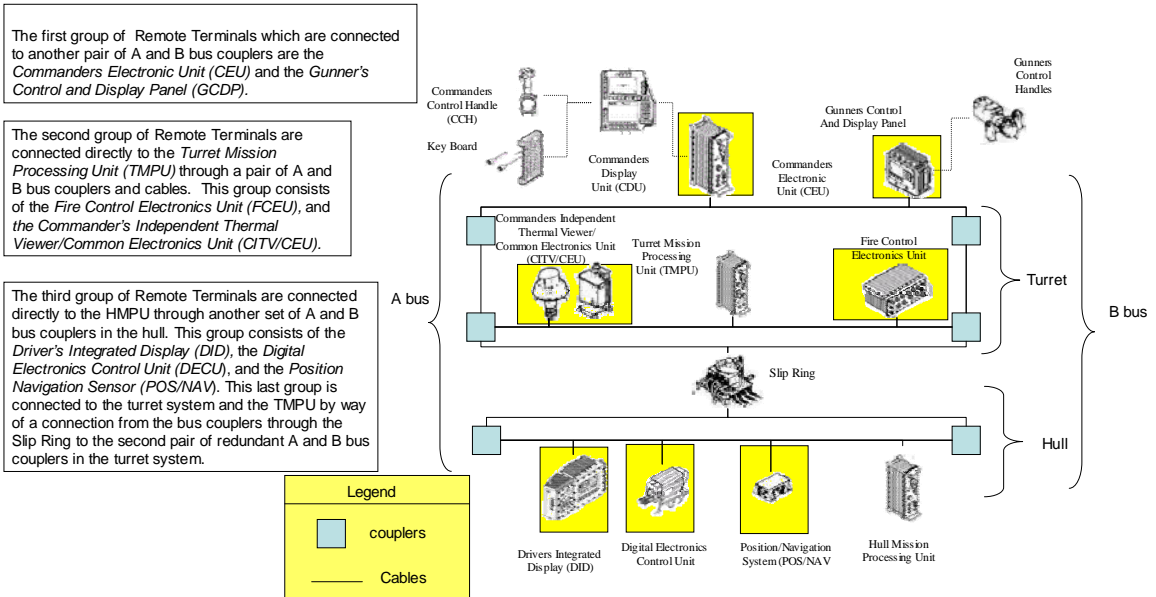


The *Remote Terminals* receive and transmit data on the bus in response to bus controller commands. They are connected to the A and B bus couplers in a specific way, such that, different Remote Terminals are connected to different A and B bus couplers. The couplers in turn are connected to each other on the A and B buses to route all information to the *TMPU* and the *HMPU*.



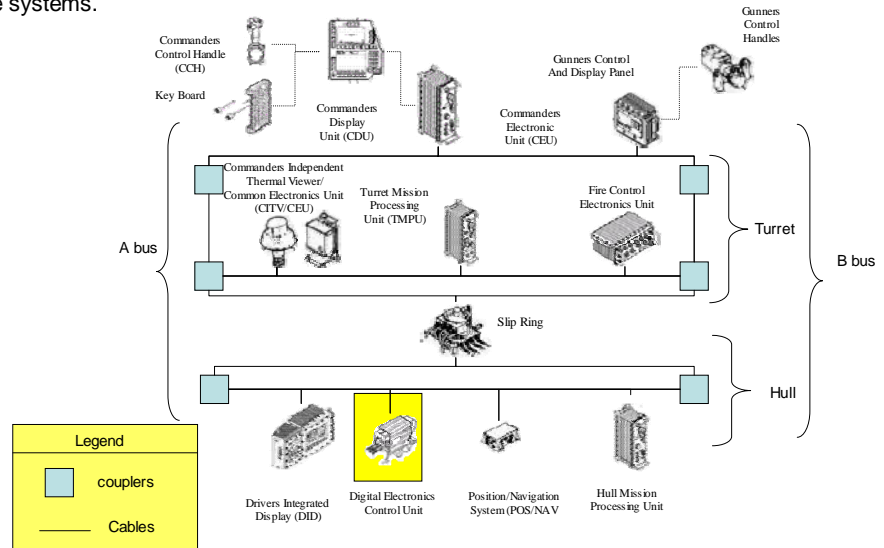
Mechanism of the Remote Terminals: The Remote Terminals are separated into three groups.

Each group of Remote Terminals is connected to a pair of A and B bus couplers.



. The Function of the Digital Electronics Control Unit (DECU):

The function of the *Digital Electronics Control Unit (DECU)* is to control certain displays within the *Driver's Integrated Display* through the 1533B bus. The DECU converts analog to digital signals and provides control and monitoring of engine systems.

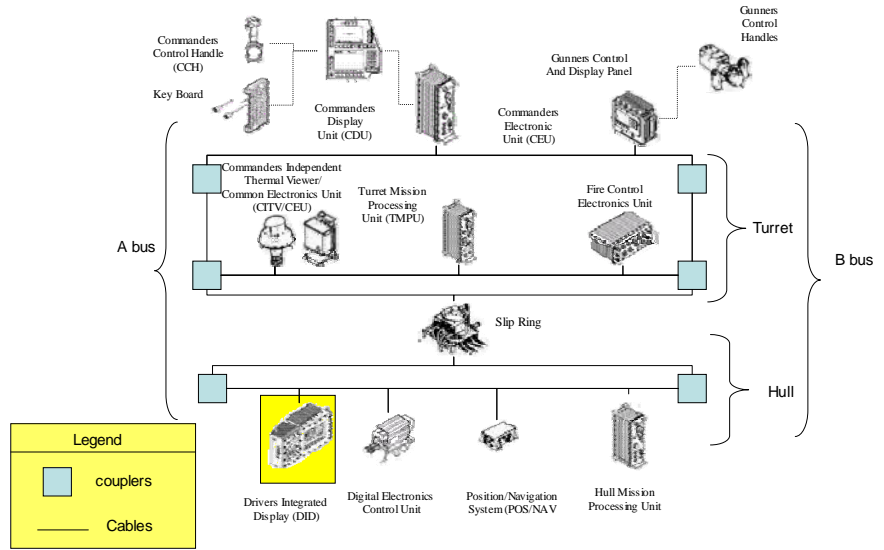


**Ask a question about the DECU and answer it.**

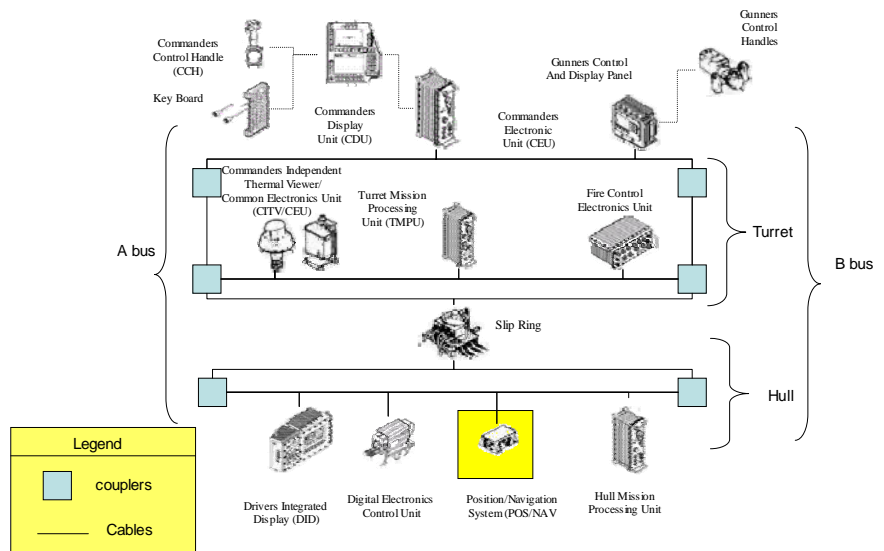


The Function of the *Driver's Integrated Display (DID)*:

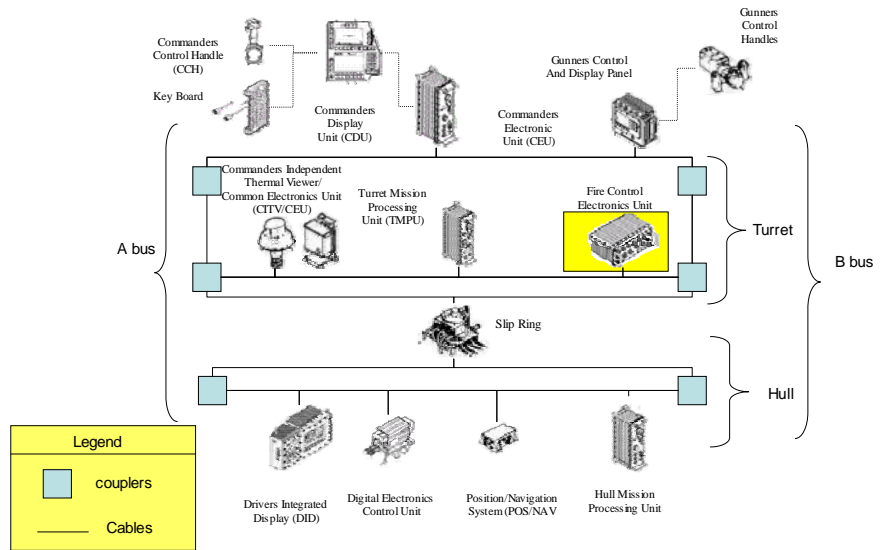
The function of the *DID* is to allow the driver access to all automotive related functions and to select back-up functions of the commander's display unit



The function of the *Position Navigation Sensor (POS/NAV)* is to provide movement and direction data for the commander, driver and the fire control system. It also provides *dynamic cant for the Fire Control System*.



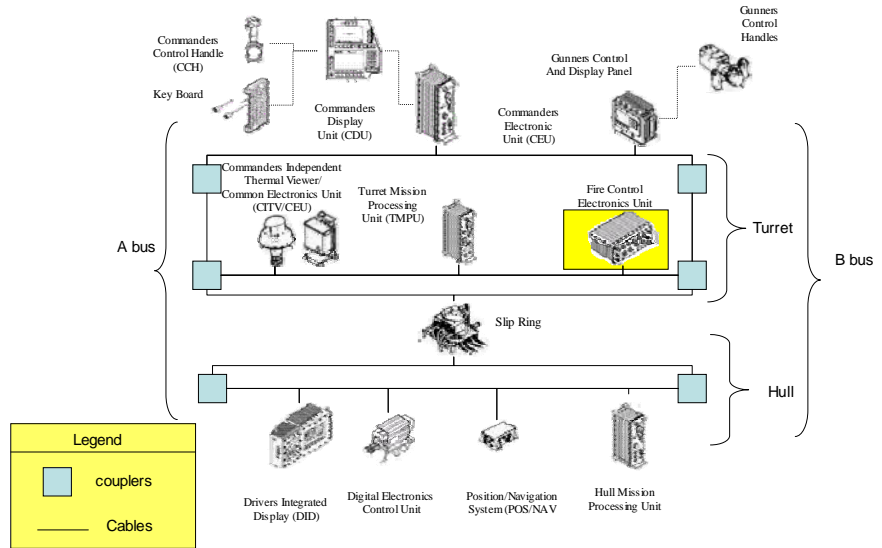
The function of the *Fire Control Electronics Unit (FCEU)*: is to integrate the Gunner's Primary Sight with the *Commander's Independent Thermal Viewer*. This allows the Commander to engage a target from the CITV or from the Gunners Primary Sight.



**Ask a question about the FCEU and answer it.**

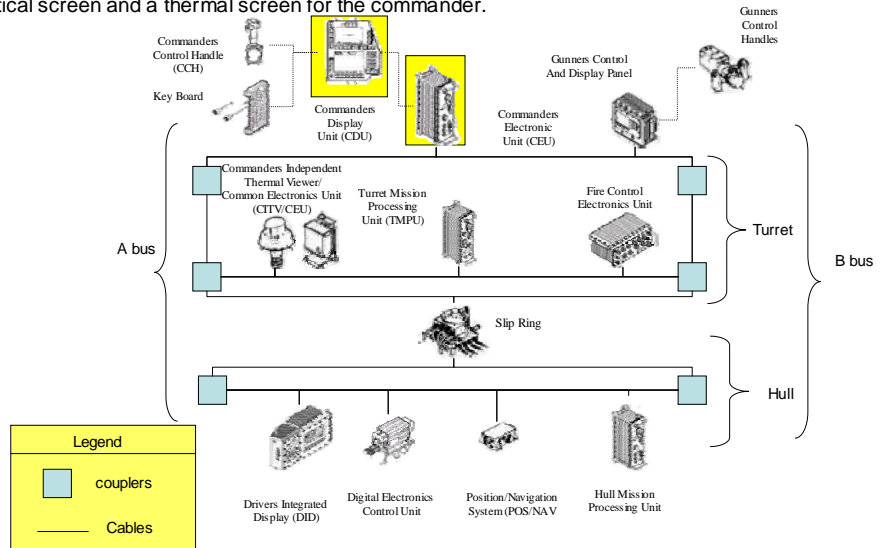
### Remote Terminal Commander's Independent Thermal Viewer/Common Electronics Unit CITV/CEU

The Function of the *Commander's Independent Thermal Viewer/ Common Electronics Unit (CITV/CEU)* is to provide the electronics to give the commander a separate stabilized thermal sight independent of turret movement and the Gunner's Primary Sight. It is independent of the Turret. It can automatically scan or be manually controlled by the commander.



### Remote Terminal Commanders Electronic Unit (CEU)

The *Commanders Electronic Unit CEU* functions to provide the Processing and memory resources for the *Commander's Display Unit* and the command, control and communications functions. It allows for the control of the commander's displays and related databases and serves as the interface to commander controlled inter-vehicular functions like map display server. It also allows interface to common and new tank components and handles passwords, reconfiguration, and radio control through the 1553B bus. It allows operation of vehicle systems and provides a tactical screen and a thermal screen for the commander.



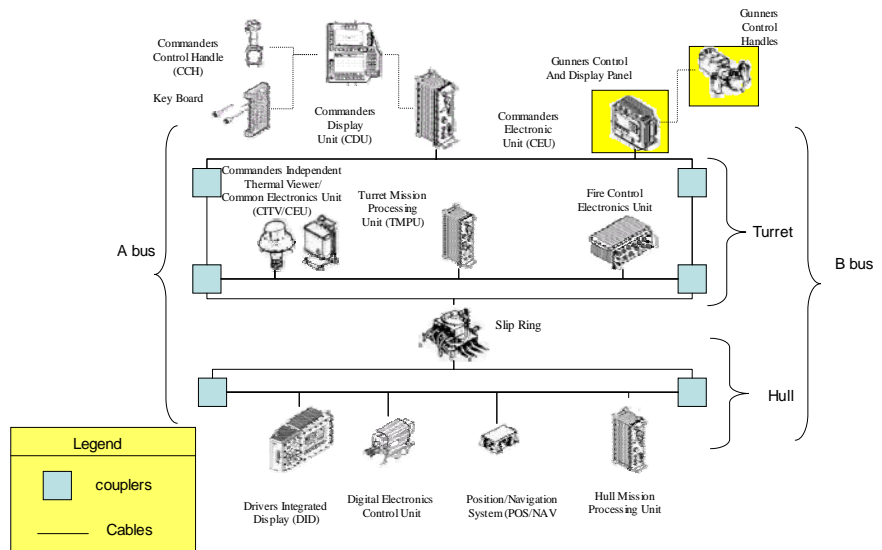
**Ask a question about the CEU and answer it.**

29

Remote Terminal Gunners Control and Display Panel  
(GCDP)

Group 1

The *Gunnery Control and Display Panel (GCDP)* provides the gunner with access to fire control functions and select backup functions for the commanders display unit. The GCDP converts analog signals from the *Gunner's Control Handles* to digital signals to be transmitted on the 1553B bus.



Begin taking test.  
Upon completion of test inform the  
monitor

## **APPENDIX F: PROVIDED ADVANCE ORGANIZER**

## **1. Organization of the content**

The curriculum you about to read is organized into five sections

- Introduce to the data bus
- Describe the Bus controller (TMPU)
- Illustrate how components are connected by cables and couplers through the slip ring
- Describe the Bus monitor (HMPU)
- Lastly, you will read about the different components of the tank

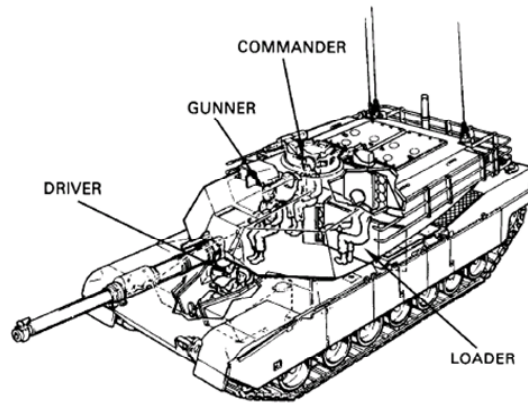
## **1. Interesting features that you will read about**

- The bus will still function even if it sustained considerable damage due to a dual redundancy feature
  - How the cables are routed along different paths throughout the tank and why
  - What component would takeover in case the bus controller is not functioning
- Couplers and their ability to ensure that failure of one component will not result in main bus failure.
- In-Tank fault diagnostic and detection
- The different displays inside the tank and how are they controlled

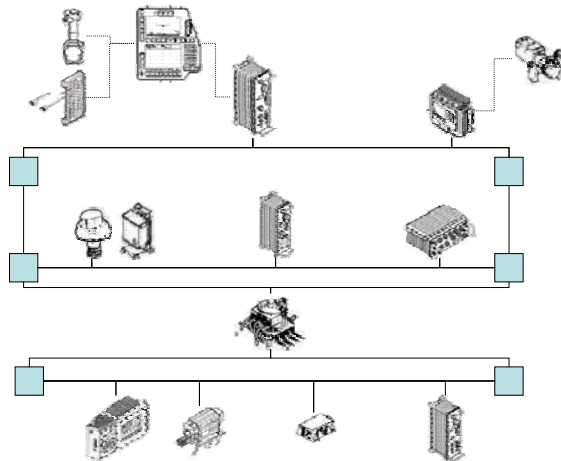
## M1A2 Tank Overview

### Objective: Familiarization with the M1A2 Tank

The M1A2 SEP combat tank uses high speed, maneuverability, and a variety of weapons to accomplish its mission. The tank provides protection from enemy weapons. It has a crew of four individuals. The driver is located in the hull the Gunner, Commander and Loader are Located in the Turret. This training will focus on the 1553B it is the data communications component of the M1A1SEP



## M1A2 Tank Function

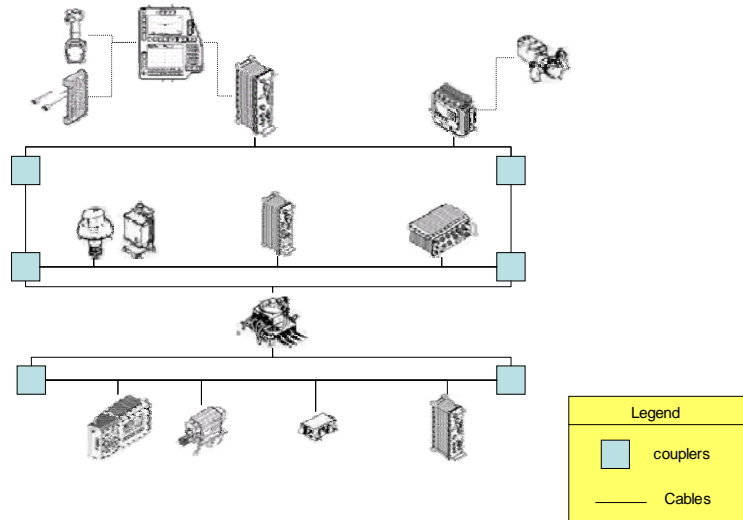


The M1A2 SEP tank system architecture is a set of distributed tank components interconnected to each other by a power distribution network and data distribution network(1553B Bus). This training will only address the 1553 Bus Data Distribution Network.



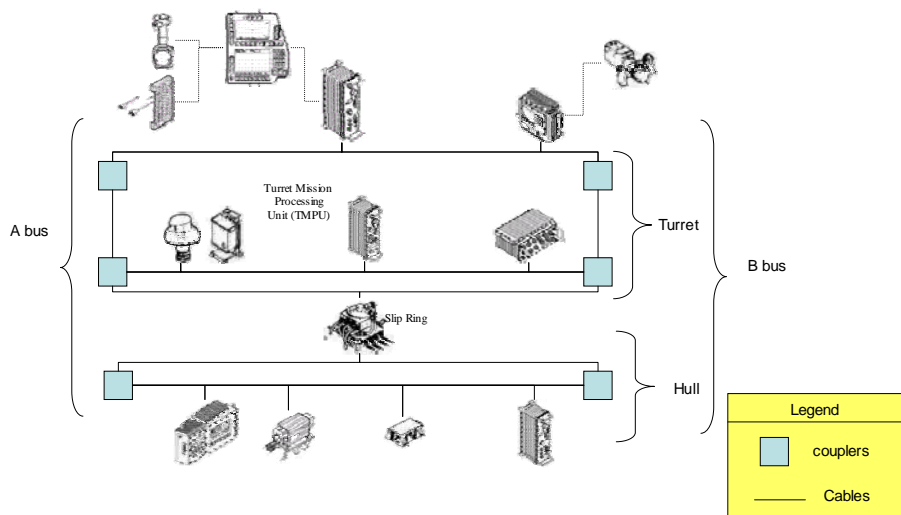
### 1553 Bus Function

Function: The 1553B Data Bus communicates all data messages to *control* and *monitor the functions and applications* of the tank. The diagram has all of the components of the 1553 Data Bus along with the wires and couplers that make up the data bus.



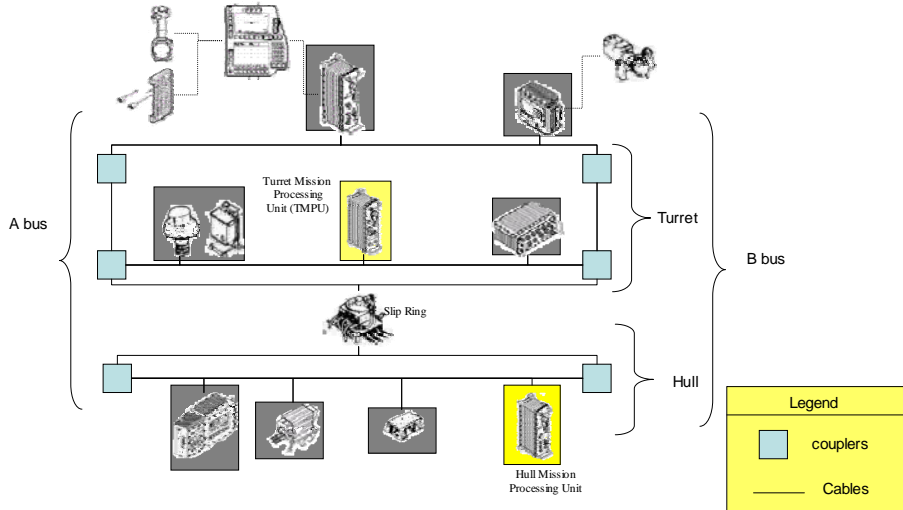
### 1553 Bus Mechanism

Mechanism: The 1553b data bus consist of a bus controller (also known as the Turret Mission Processor Unit) that *transmits* and *receives messages* across cables, through the slip ring and couplers. The controller communicates to a monitor and other remote terminals on this bus. This 1553b data bus is *dual redundant* with both an A bus and a B bus. It serves both turret functions and some hull functions.



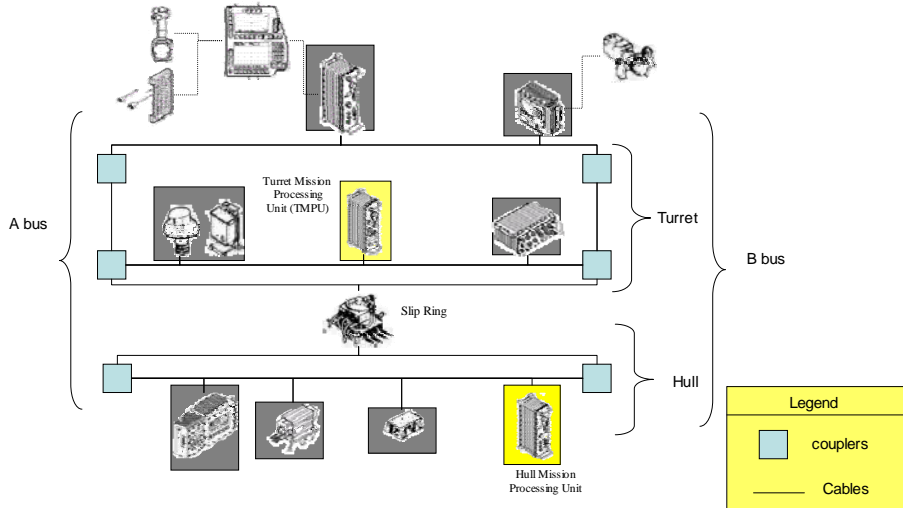
Function: The A and the B buses insure dual redundancy in the system. They distribute messages to all of *Remote Terminals* and the *Bus Monitor/Hull Mission Processing Unit (HMPU)* from and to the *Turret Mission Processing Unit (TMPU)*. If any bus is damaged the other bus, either the A or B bus which is not damaged, can still transmit information between the *Remote Terminals* and the *Turret Mission Processing Unit (TMPU)*.

Mechanism: The A bus and B bus consist of a series of cables and couplers that connect the *Bus Controller*, *Bus Monitor* and *Remote Terminals*.

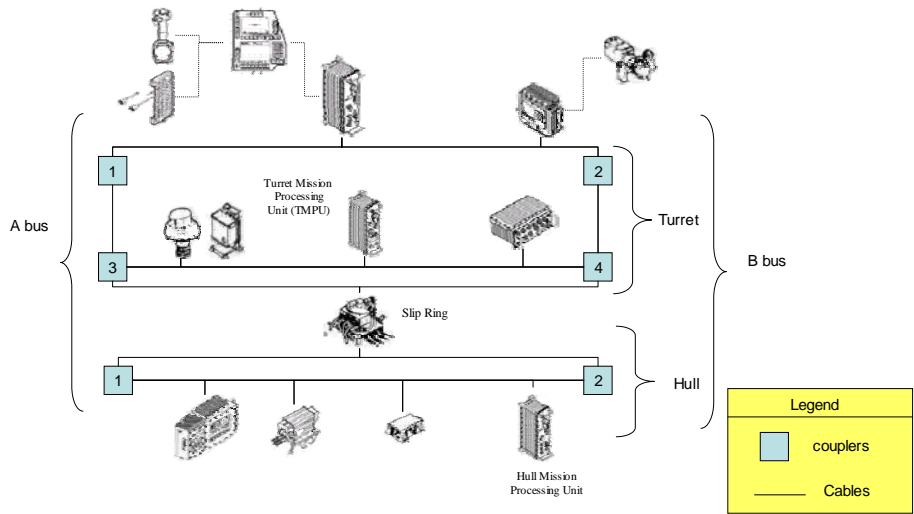


The A and B bus couplers distribute data and messages by bus cables to different Remote Terminals. They connect the *Bus Controller (Turret Mission Processing Unit TMPU)* and *Bus Monitor (Hull Mission Processing Unit HMPU)* to different *Remote Terminals*.

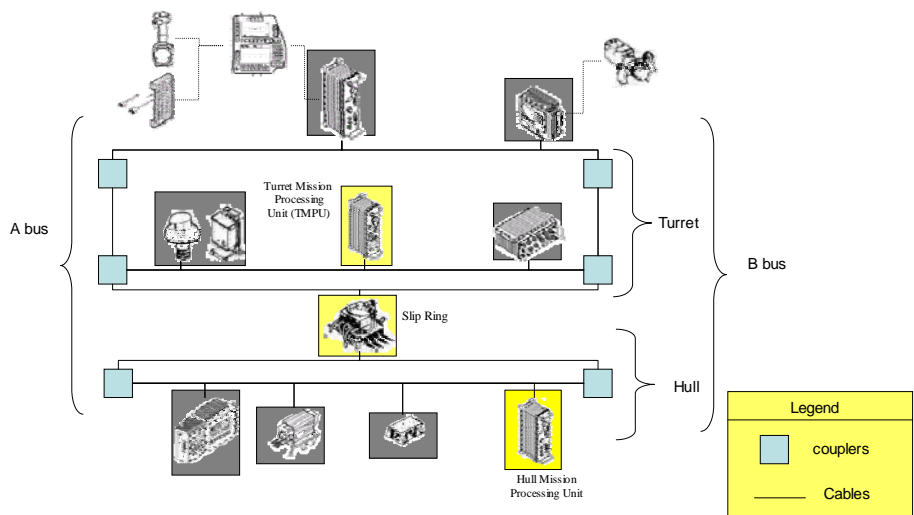
Bus Couplers isolate the A and B Bus to ensure that failure of one of the *Remote Terminal Units*, the *Turret Mission Processing Unit (TMPU)* or the *Hull Mission Processing Unit (HMPU)* will not result in main bus failure. They ACT AS A SURGE Protector protecting other components.



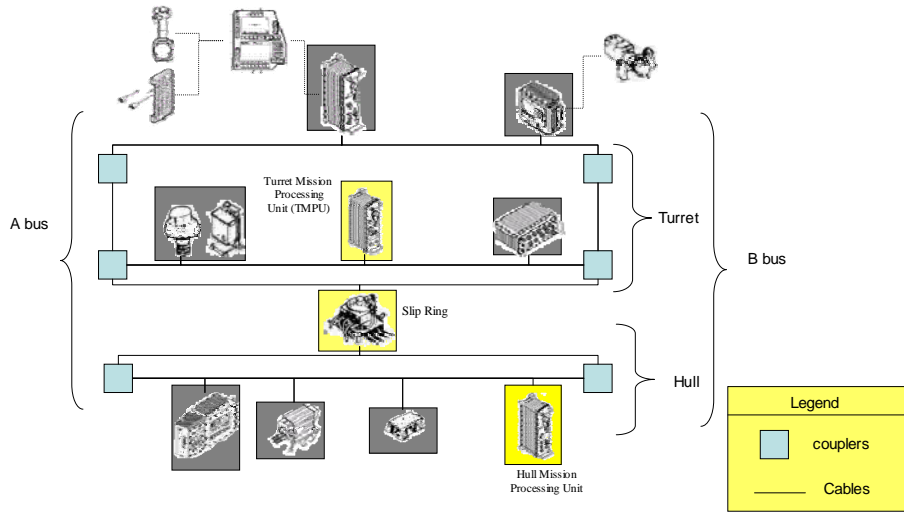
Four bus couplers are located in the *turret* and two are located in the *hull* in different locations. They are connected via cables and the slip ring. The couplers connected by cables routed along different paths to provide redundant capability.



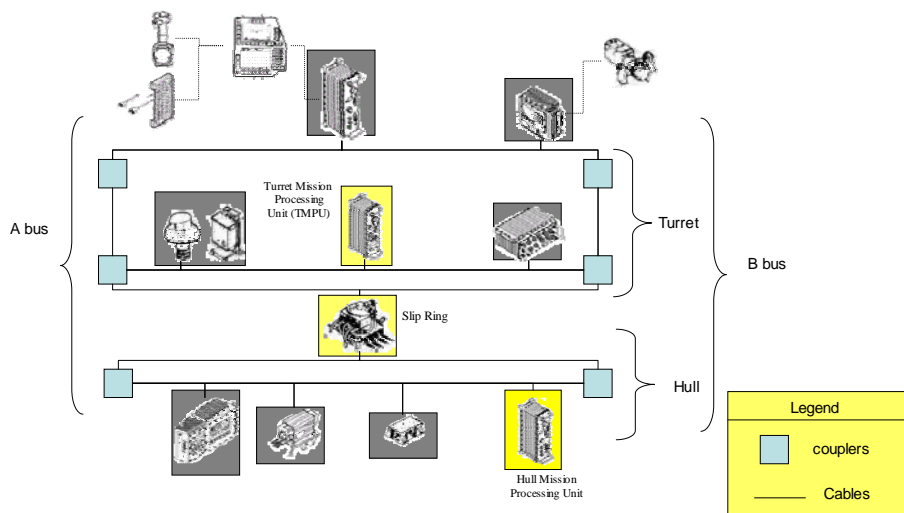
Function: The bus cables are the communication lines between the components of the bus system. They carry all information between components.



Mechanism: *Data bus cables* are a twisted pair of wires, which are shielded and connected to the *Turret Mission Processing Unit (TMPU)*, the *Hull Mission Processing Unit (HMPU)* and other *Remote Terminals*. The cables connect the *TMPU* and the *HMPU* and *Remote Terminals* to the *A bus couplers* and *B bus couplers*. Cables connect to the slip ring so the connection from the *turret* to the *hull* can be made. The cables are routed on different sides of the vehicle to provide redundant capability

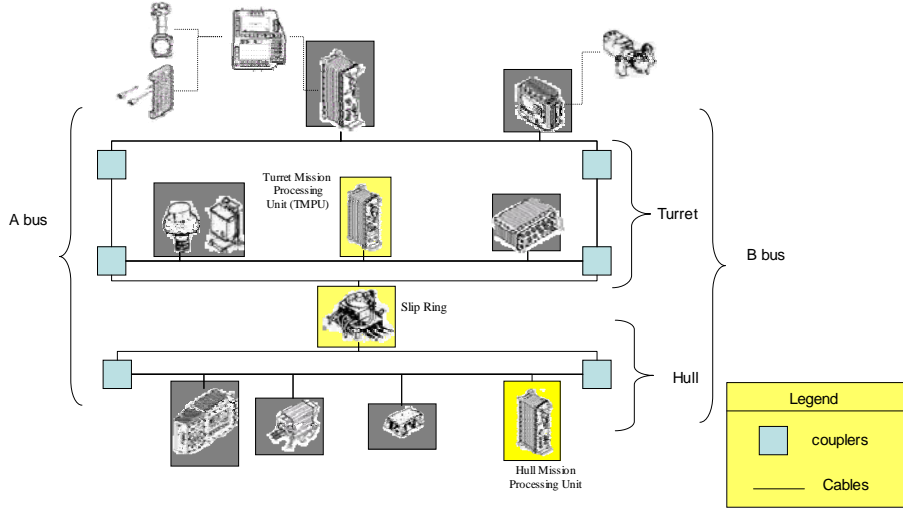


Function: The *Slip Ring* forms the communications link between the two A bus couplers and two B bus couplers which serve the Turret and one A bus coupler and one B bus coupler which serve the Hull.

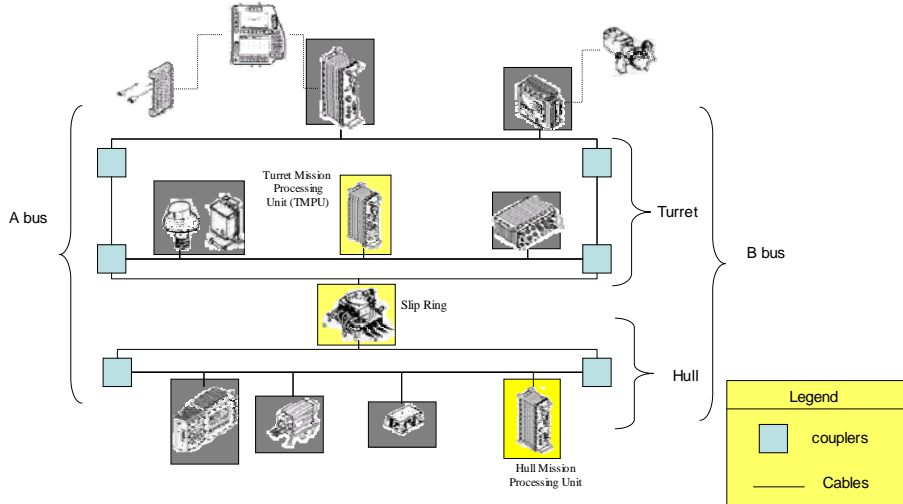


Function: The bus controller is referred to as the *Turret Mission Processing Unit (TMPU)*. It sends and controls the flow of messages across cables through couplers and their cables to remote terminals.

The *TMPU* is also responsible for conducting all system diagnostic checks and for calculating ballistic solutions for the tank under normal operations. These diagnostic and ballistic functions make the *TMPU* like another remote terminal.

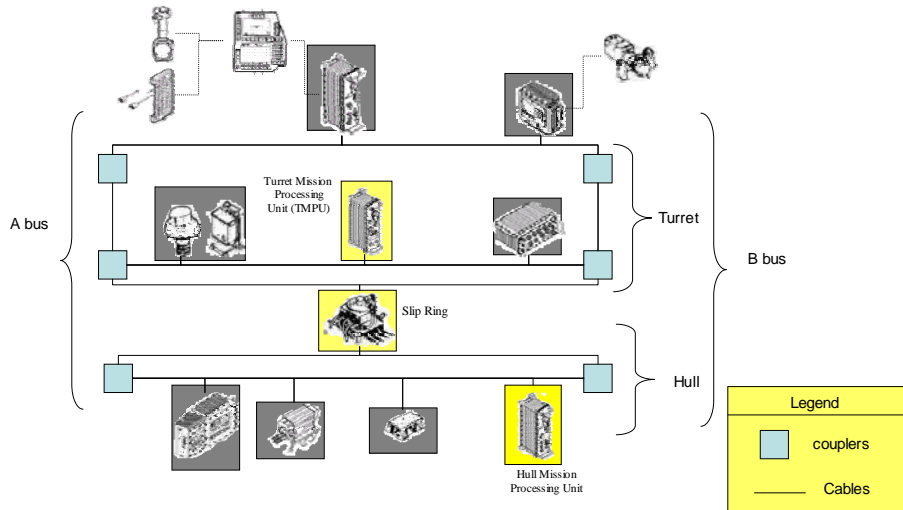


Mechanism: The *TMPU* communicates to *Remote Terminals* through redundant A and B buses. The *TMPU* consists of many computer processors which *control and manage* information transmission throughout the tank Turret systems and the Hull systems by way of cables and couplers. The *TMPU* talks to the *Bus Monitor* referred to as the *Hull Mission Processing Unit (HMPU)* through the A bus and B bus via the slip ring. The *TMPU* by way of the A and B buses can talk to all Remote Terminals, which perform various functions. The *TMPU* can control the talk between any two *Remote Terminals* by way of the A and B buses. Only one terminal can talk to one terminal at a time and the sequence in which any two terminals can talk is established by a fixed priority by the bus controller.



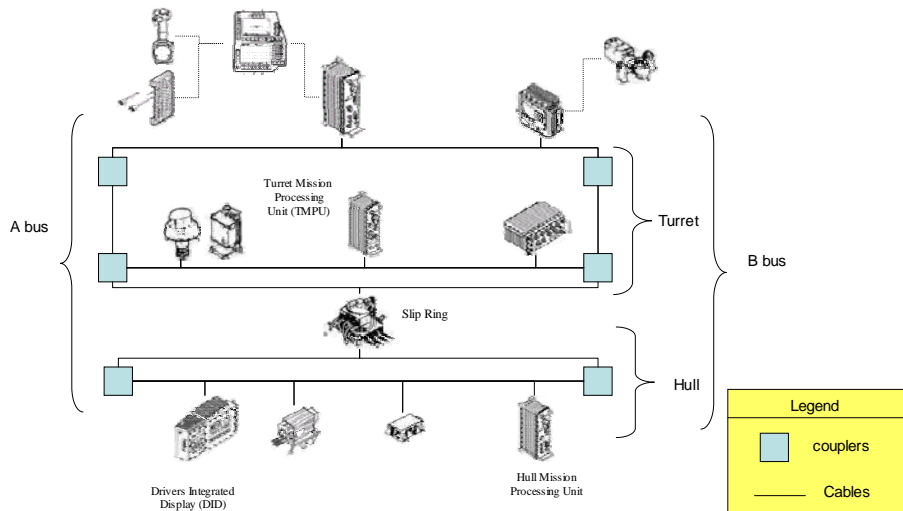
14 Fire Control Function and Mechanism of the Turret Mission Processing Unit Group 1

One of the *TMPU's* Remote Terminal functions is calculating ballistic solutions for the Fire Control System. It does this by storing and managing *critical data* such as Boresight data, plumb and sync., scan limits and rate, all drift data, ammo type, all zero data, Commander's Independent Thermal Viewer adjustments, and Sensor inputs for crosswind, cant, lead, ammo temperature and battle-sight range which is then used to *compute solutions for the fire control system employing the processors and the software of the TMPU.*



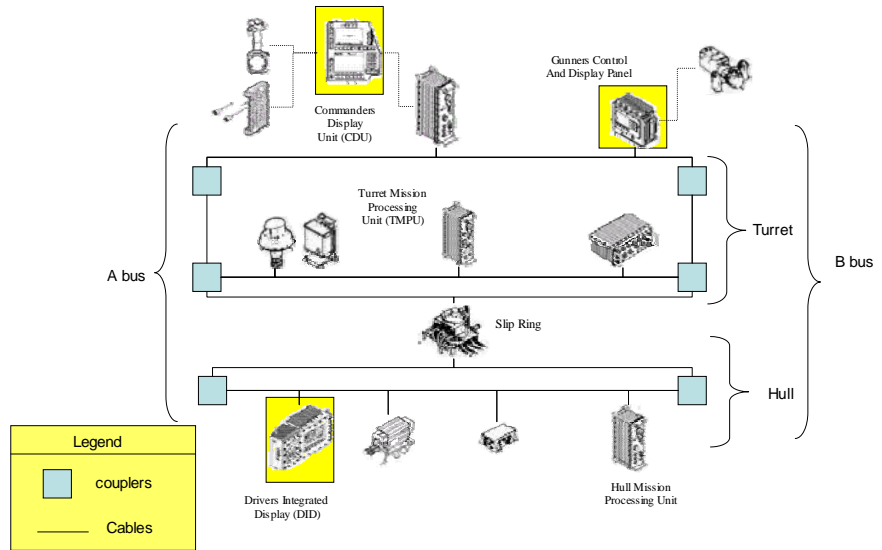
15 Remote Terminal Function of the Turret Mission Processing Unit: Diagnostic Group 1

Another Remote Terminal-like function of the Turret Mission Processing Unit (TMPU) is *diagnosing system components.* There are three different types of test, the *Self-Test (ST)*, the *Built in Test (BIT)* and the *Fault Isolation Test (FIT).*



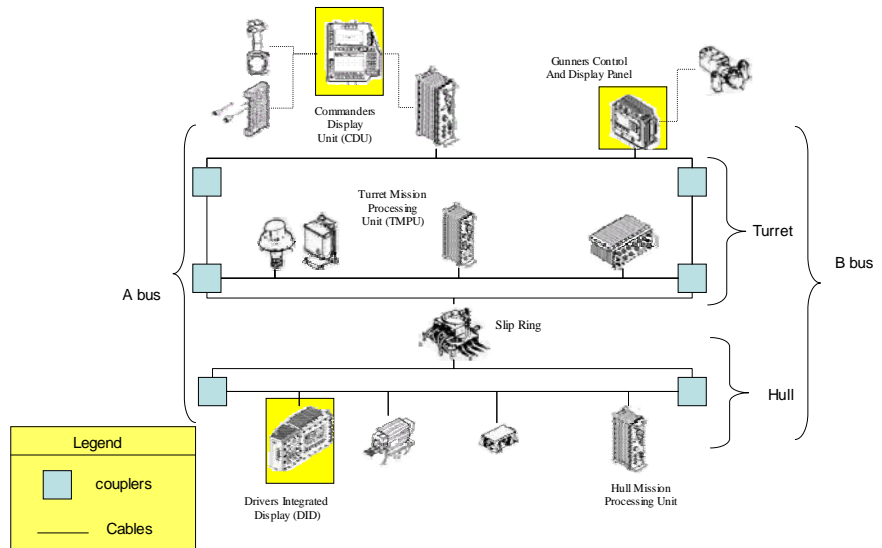
16 Remote Terminal Mechanism of the Turret Mission Processing Unit: Self Test Group 1

*Self-Test* is designed to run in the background without interfering with normal operations. If a fault is detected by the *Self-Test*, a caution or warning message is displayed in one of three locations; the *Commander's Display Unit*, the *Gunner's Control Display Panel* or the *Driver's Integrated Display*. This is an automatic test and runs constantly in the background.



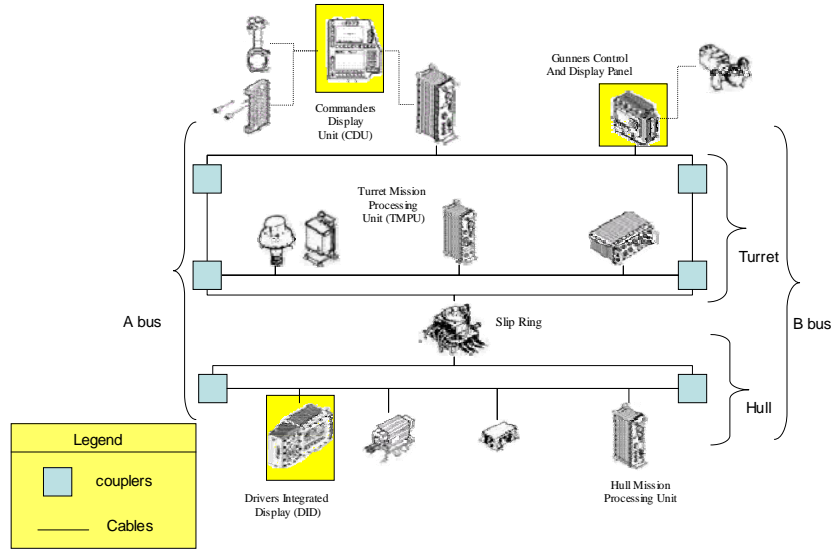
17 Remote Terminal Mechanism of the Turret Mission Processing Unit: Built In Test Group 1

The *Built in Test* is designed to provide extensive and comprehensive test coverage of the component in which the *BIT* is embedded. The *BIT* is an intrusive test which requires components to be shut down. When a fault is detected by *BIT* in its related component, it will display a NOGO message on the *Commander's Display Unit*, the *Gunner's Control Display Panel* or the *Driver's Integrated Display* to alert the crew or mechanic that a fault has occurred



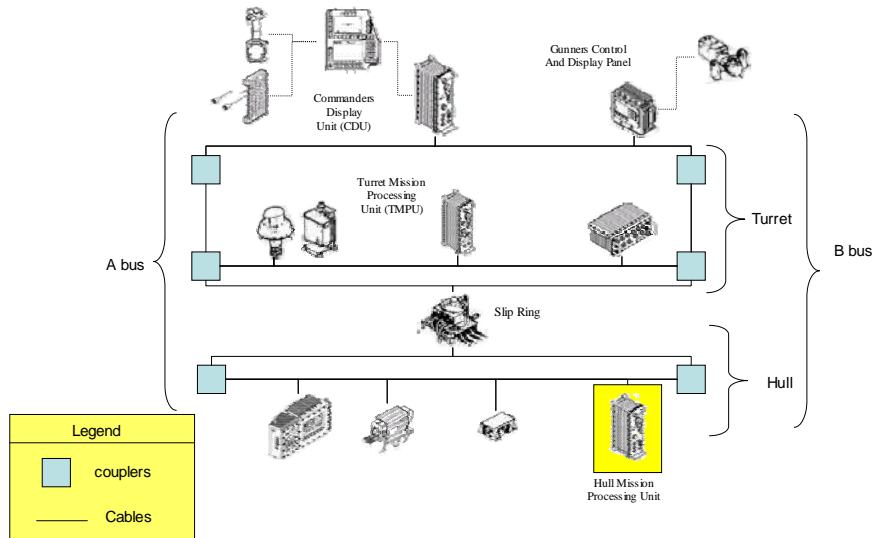
### Remote Terminal Mechanism of the Turret Mission Processing Unit: Fault Isolation Test

The *Fault Isolation Test (FIT)* is designed to pinpoint a fault within a group of detected failures or support further testing of the system beyond the capabilities of the *Self-Test* or the *Built-In test*. Maintenance personnel will conduct *FIT* from the *Commander's Display Unit*, the *Gunner's Control Display Panel* or the *Driver's Integrated Display* depending upon the type of fault detected.



### Bus Monitor/HMPU Function

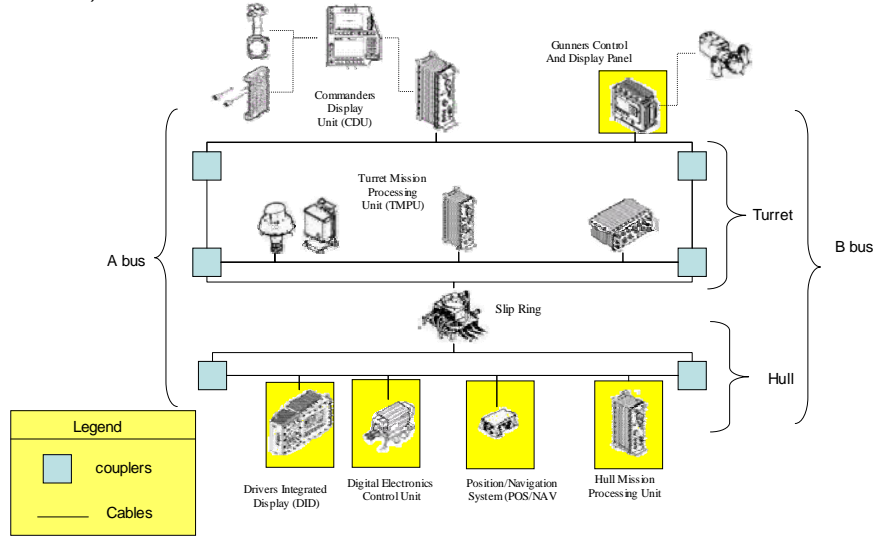
Function: The *Bus Monitor* or the *Hull Mission Processing Unit (HMPU)* is the *backup* for the *Bus Controller* or *Turret Mission Processing Unit (TMPU)*. If the *TMPU* fails, the *HMPU* can carry out all of the *Bus Controller* functions *except for the use of Global Positioning System information*. Global Positioning System information used for position information is fed directly to the *TMPU* and cannot be accessed by the *HMPU*. *This is the only function which is not dual redundant in the 1553B bus system*. The *HMPU*, like the *TMPU* can send messages across cables through couplers and their cables to remote terminals in the Hull and through cables, couplers and the slip ring to the remote terminals in the turret.





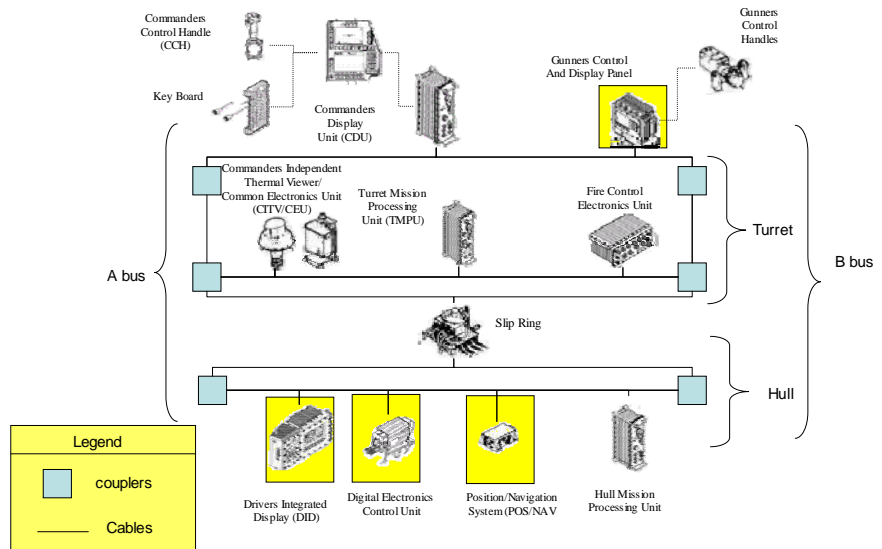
Bus Monitor/HMPU Mechanism

Mechanism: The *Hull Mission Processing Unit (HMPU)* is also connected to two couplers one on the A bus and one on the B bus in the same way as the *Turret Mission Processing Unit (TMPU)*. This makes up six couplers in all with the addition of the two A and two B bus couplers of the Turret system. Three on the A bus and three on the B bus. The other Remote terminals which are connected along with the HMPU to these two couplers are: The *Driver's Integrated Display Unit (DID)*, the *Digital Electronics Control Unit (DECU)* and the *Position Navigation (POS/NAV) sensor*.



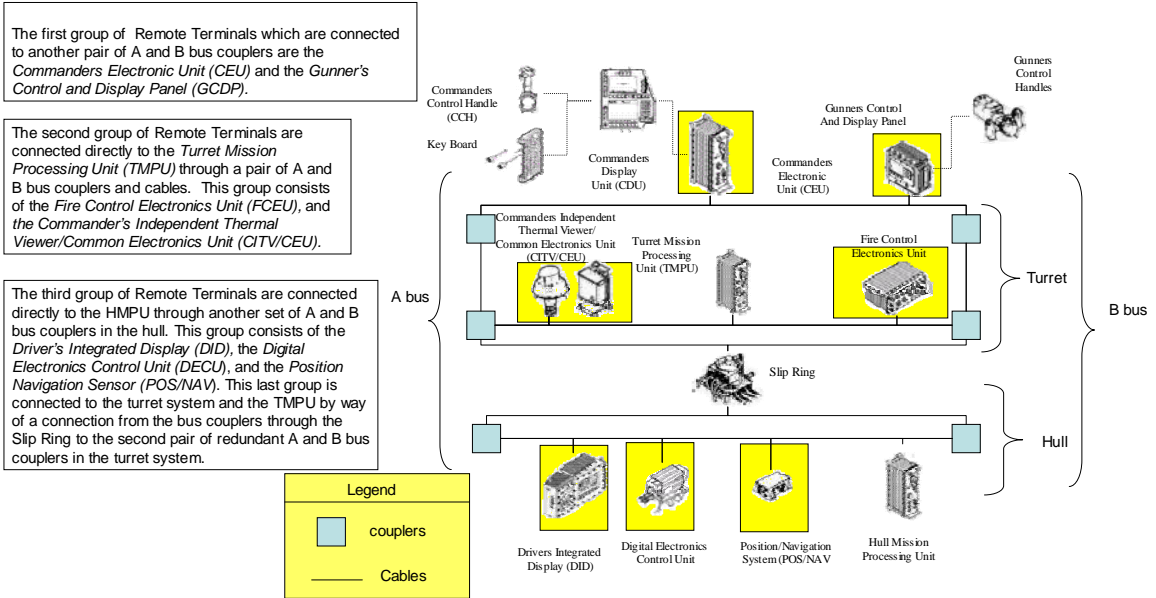
Remote Terminals Functions

The *Remote Terminals* receive and transmit data on the bus in response to bus controller commands. They are connected to the A and B bus couplers in a specific way, such that, different Remote Terminals are connected to different A and B bus couplers. The couplers in turn are connected to each other on the A and B buses to route all information to the *TMPU* and the *HMPU*.



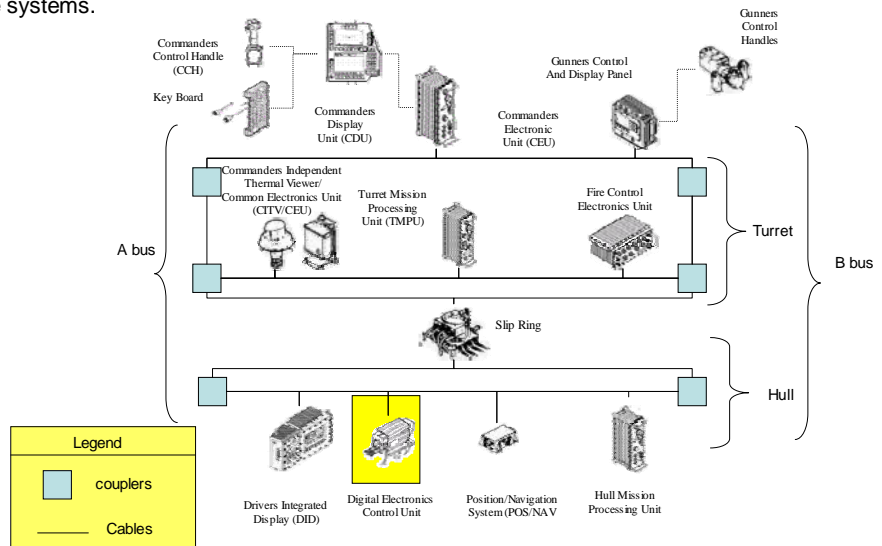
Mechanism of the Remote Terminals: The Remote Terminals are separated into three groups.

Each group of Remote Terminals is connected to a pair of A and B bus couplers.



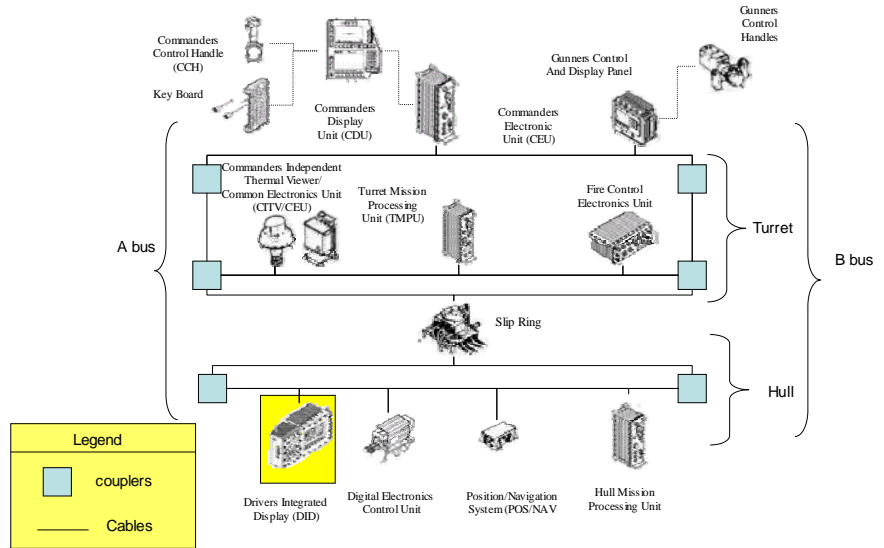
. The Function of the Digital Electronics Control Unit (DECU):

The function of the *Digital Electronics Control Unit (DECU)* is to control certain displays within the *Driver's Integrated Display* through the 1533B bus. The DECU converts analog to digital signals and provides control and monitoring of engine systems.

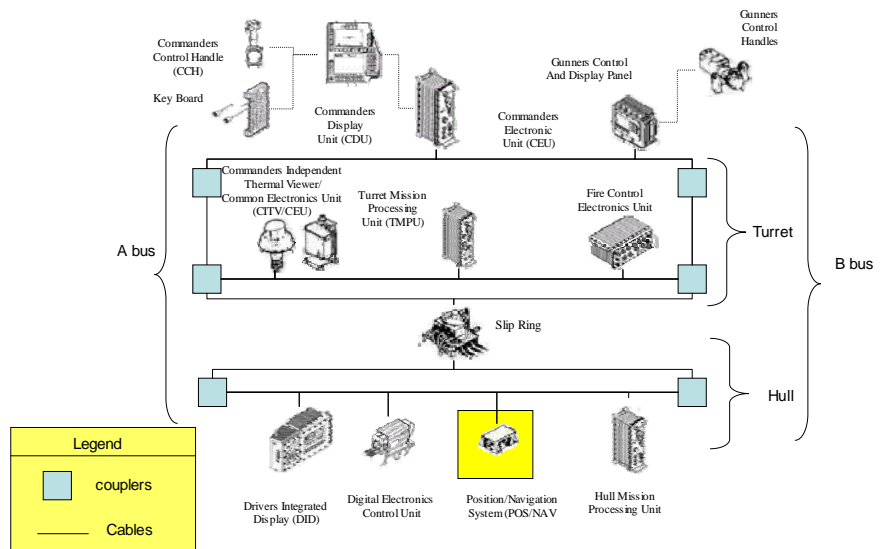


The Function of the *Driver's Integrated Display (DID)*:

The function of the *DID* is to allow the driver access to all automotive related functions and to select back-up functions of the commander's display unit

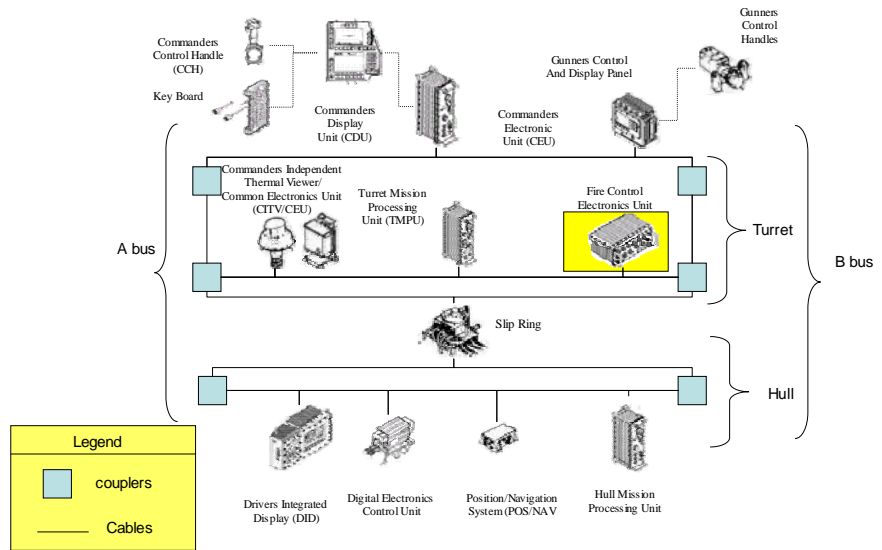


The function of the *Position Navigation Sensor (POS/NAV)* is to provide movement and direction data for the commander, driver and the fire control system. It also provides *dynamic cant for the Fire Control System*.



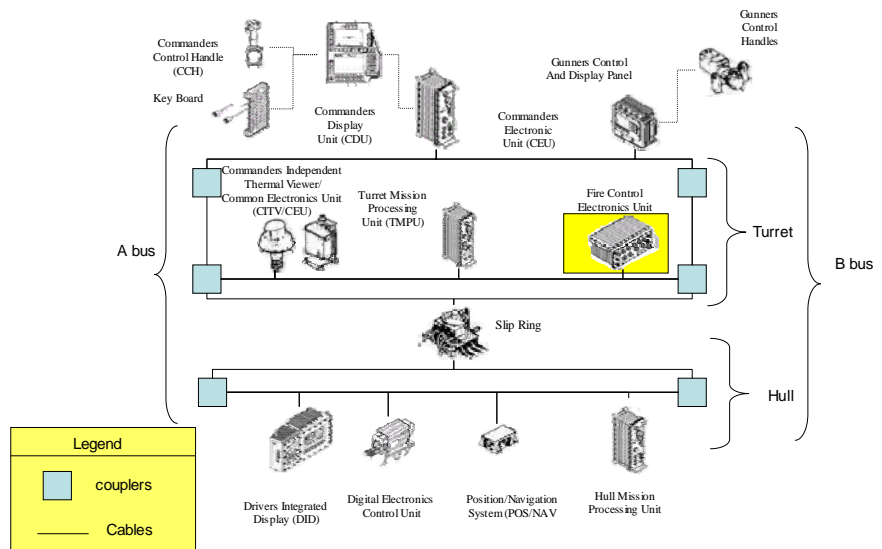
### Remote Terminal Fire Control Electronics Unit (FCEU)

The function of the *Fire Control Electronics Unit (FCEU)*: is to integrate the Gunner's Primary Sight with the *Commander's Independent Thermal Viewer*. This allows the Commander to engage a target from the CITV or from the Gunners Primary Sight.



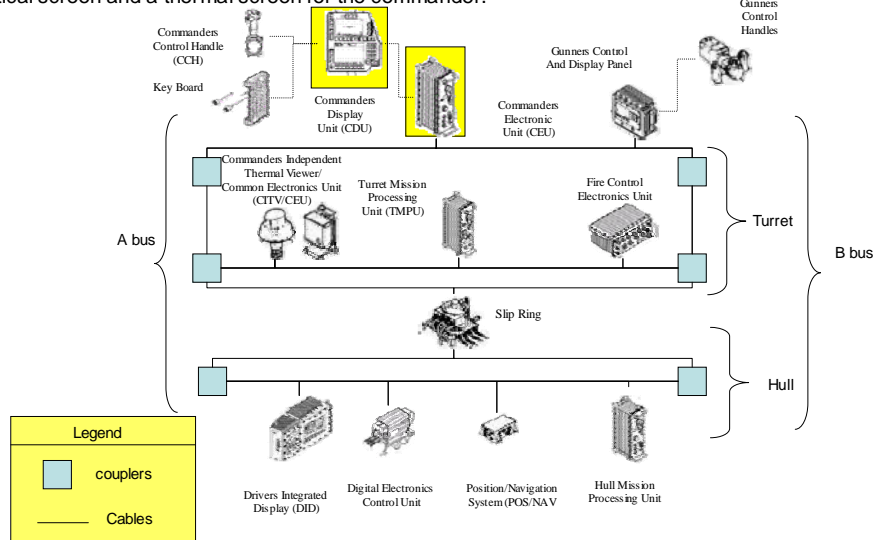
### Remote Terminal Commander's Independent Thermal Viewer/Common Electronics Unit CITV/CEU

The Function of the *Commander's Independent Thermal Viewer/ Common Electronics Unit (CITV/CEU)* is to provide the electronics to give the commander a separate stabilized thermal sight independent of turret movement and the Gunner's Primary Sight. It is independent of the Turret. It can automatically scan or be manually controlled by the commander.



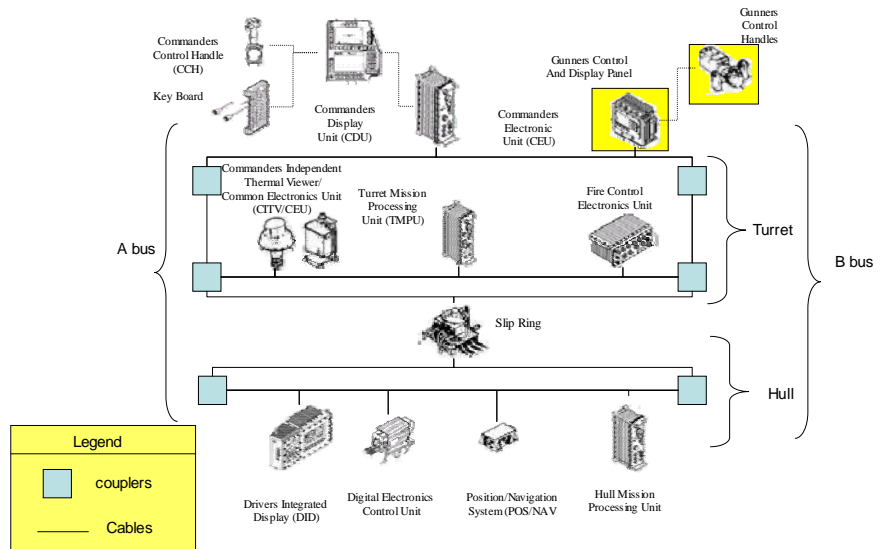
### Remote Terminal Commanders Electronic Unit (CEU)

The *Commanders Electronic Unit CEU* functions to provide the Processing and memory resources for the *Commander's Display Unit* and the command, control and communications functions. It allows for the control of the commander's displays and related databases and serves as the interface to commander controlled inter-vehicular functions like map display server. It also allows interface to common and new tank components and handles passwords, reconfiguration, and radio control through the 1553B bus. It allows operation of vehicle systems and provides a tactical screen and a thermal screen for the commander.



### Remote Terminal Gunners Control and Display Panel (GCDP)

The *Gunners Control and Display Panel (GCDP)* provides the gunner with access to fire control functions and select backup functions for the commanders display unit. The GCDP converts analog signals from the *Gunner's Control Handles* to digital signals to be transmitted on the 1553B bus.



Begin taking test.  
Upon completion of test inform the  
monitor

## **APPENDIX G: GENERATED ADVANCE ORGANIZER**

After you completed your reading, you will be asked to describe how the curriculum is organized. Your organization should address the important concepts of the curriculum. You will be asked to present your organization in a nested bullets format, like the example below:

#### University Park Colleges and Departments

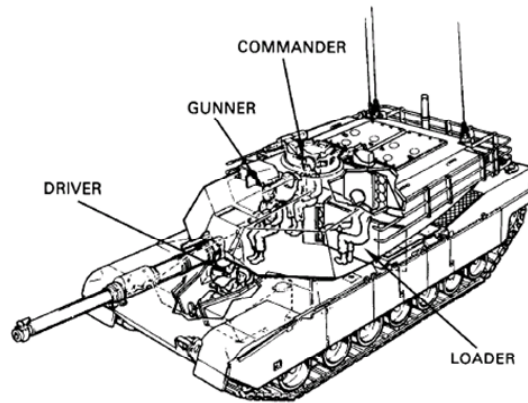
1. Agricultural Sciences
  - A. Agricultural and Biological Engineering
  - B. Agricultural Economics
  - C. ...
2. Arts and Architecture
  - A. Architecture and Landscape Architecture
    - i. Department of Architecture
    - ii. Department of Landscape Architecture
    - iii. ...
  - B. Art History
  - C. ...
3. ...



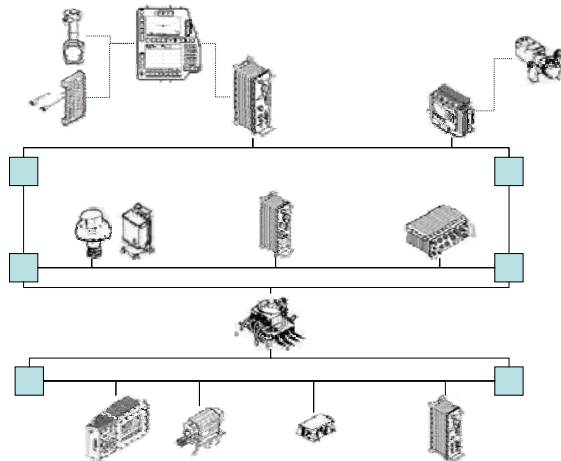
## M1A2 Tank Overview

### Objective: Familiarization with the M1A2 Tank

The M1A2 SEP combat tank uses high speed, maneuverability, and a variety of weapons to accomplish its mission. The tank provides protection from enemy weapons. It has a crew of four individuals. The driver is located in the hull the Gunner, Commander and Loader are Located in the Turret. This training will focus on the 1553B it is the data communications component of the M1A1SEP



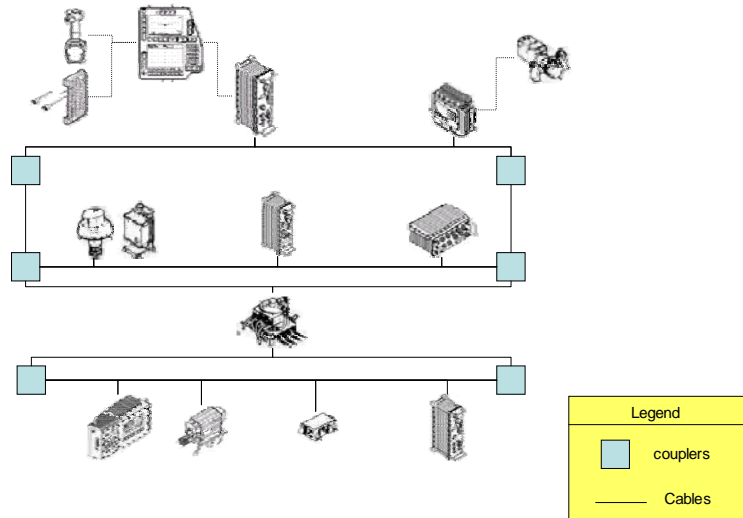
## M1A2 Tank Function



The M1A2 SEP tank system architecture is a set of distributed tank components interconnected to each other by a power distribution network and data distribution network(1553B Bus). This training will only address the 1553 Bus Data Distribution Network.

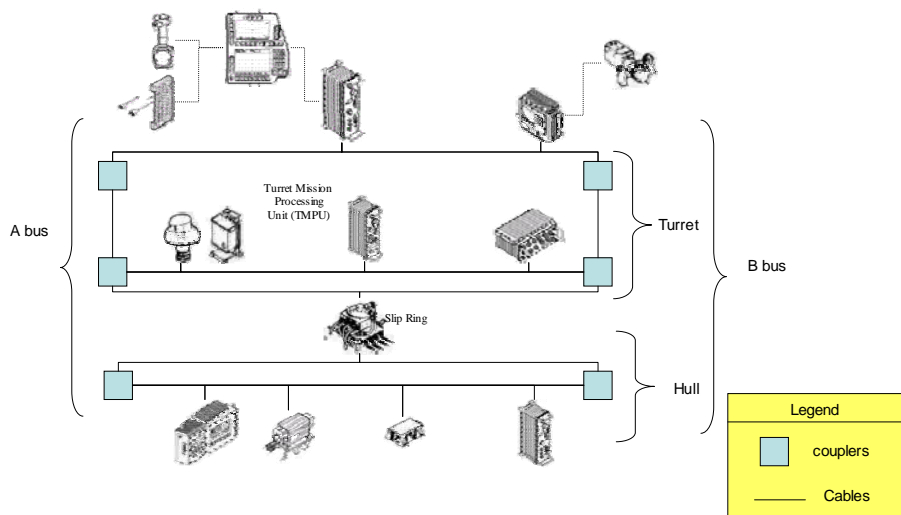
## 1553 Bus Function

Function: The 1553B Data Bus communicates all data messages to *control* and *monitor the functions and applications* of the tank. The diagram has all of the components of the 1553 Data Bus along with the wires and couplers that make up the data bus.



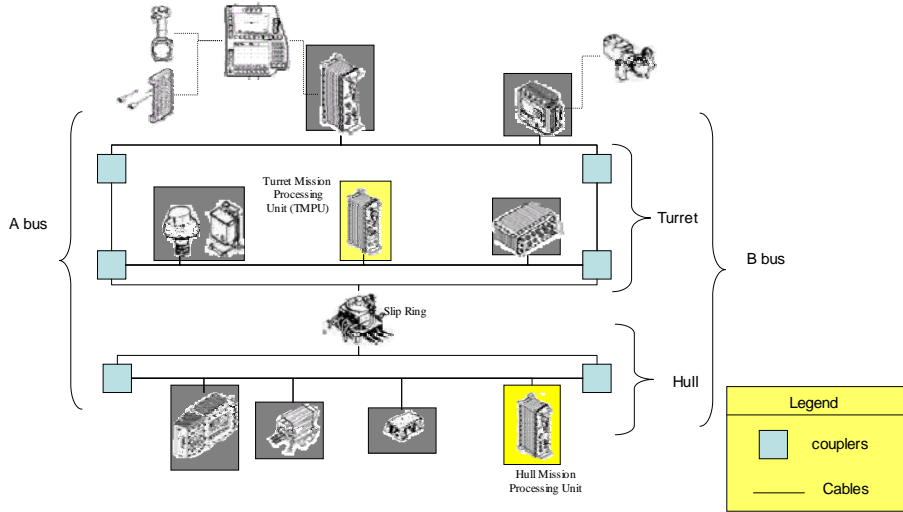
## 1553 Bus Mechanism

Mechanism: The 1553b data bus consist of a bus controller (also known as the Turret Mission Processor Unit) that *transmits* and *receives messages* across cables, through the slip ring and couplers. The controller communicates to a monitor and other remote terminals on this bus. This 1553b data bus is *dual redundant* with both an A bus and a B bus. It serves both turret functions and some hull functions.



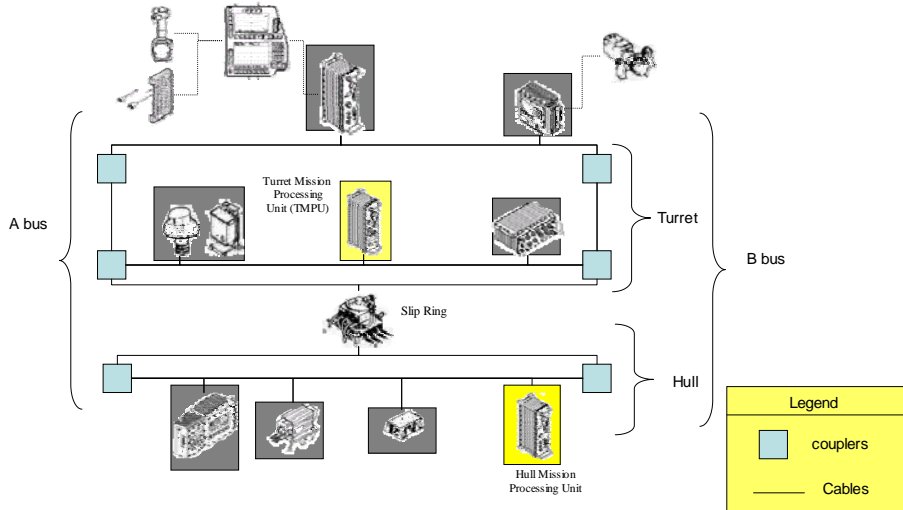
Function: The A and the B buses insure dual redundancy in the system. They distribute messages to all of *Remote Terminals* and the *Bus Monitor/Hull Mission Processing Unit (HMPU)* from and to the *Turret Mission Processing Unit (TMPU)*. If any bus is damaged the other bus, either the A or B bus which is not damaged, can still transmit information between the *Remote Terminals* and the *Turret Mission Processing Unit (TMPU)*.

Mechanism: The A bus and B bus consist of a series of cables and couplers that connect the *Bus Controller*, *Bus Monitor* and *Remote Terminals*.

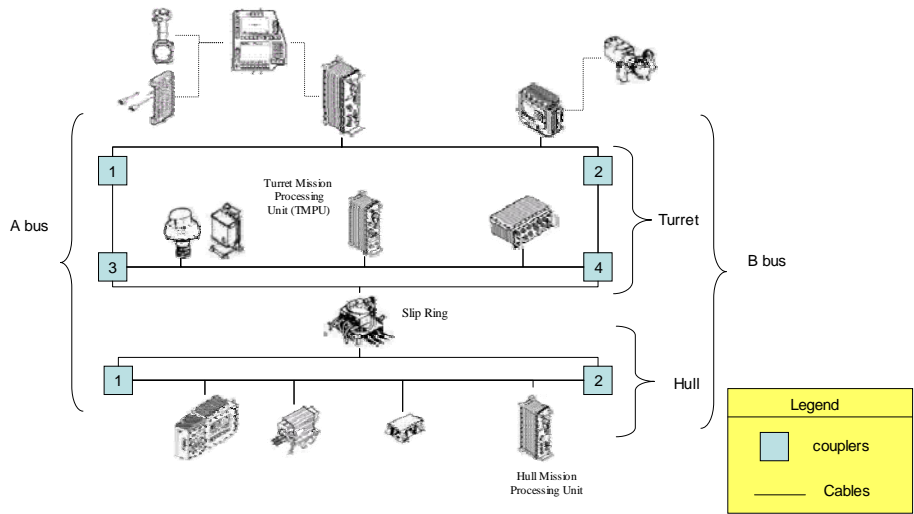


The A and B bus couplers distribute data and messages by bus cables to different Remote Terminals. They connect the *Bus Controller (Turret Mission Processing Unit TMPU)* and *Bus Monitor (Hull Mission Processing Unit HMPU)* to different *Remote Terminals*.

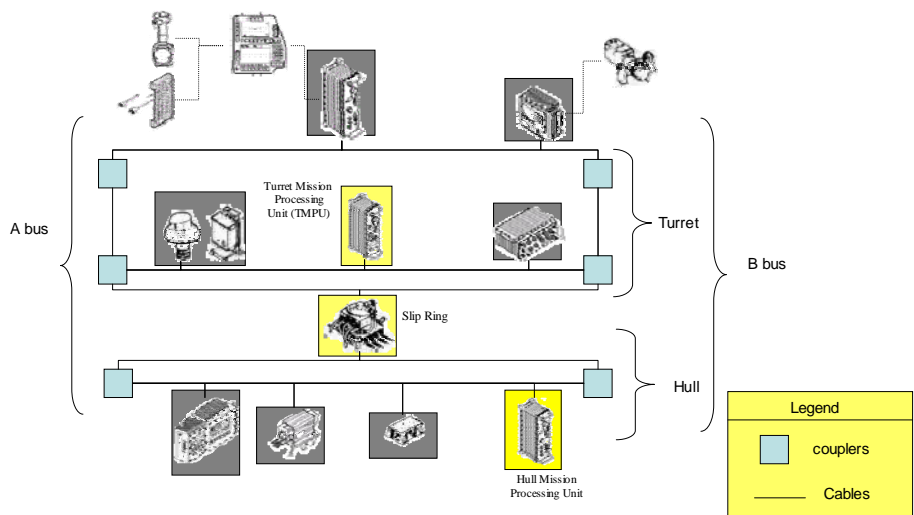
Bus Couplers isolate the A and B Bus to ensure that failure of one of the *Remote Terminal Units*, the *Turret Mission Processing Unit (TMPU)* or the *Hull Mission Processing Unit (HMPU)* will not result in main bus failure. They ACT AS A SURGE Protector protecting other components.



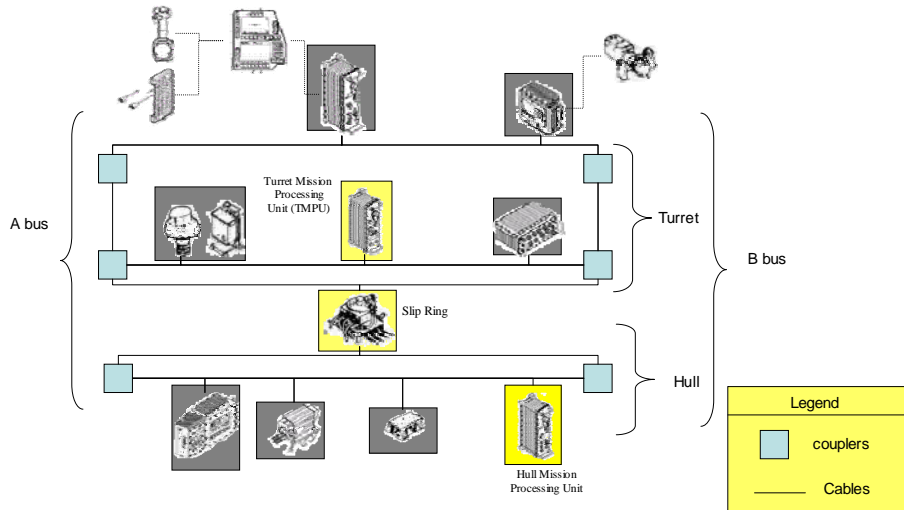
Four bus couplers are located in the *turret* and two are located in the *hull* in different locations. They are connected via cables and the slip ring. The couplers connected by cables routed along different paths to provide redundant capability.



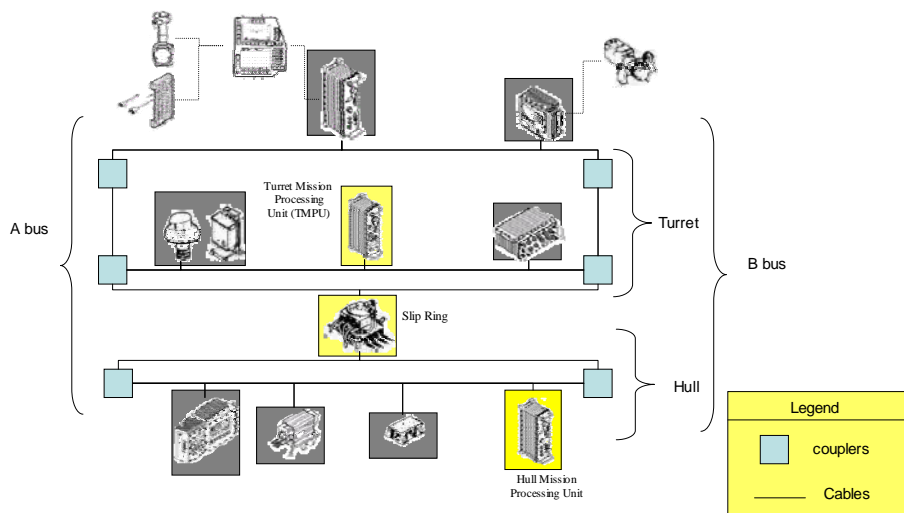
Function: The bus cables are the communication lines between the components of the bus system. They carry all information between components.



Mechanism: *Data bus cables* are a twisted pair of wires, which are shielded and connected to the *Turret Mission Processing Unit (TMPU)*, the *Hull Mission Processing Unit (HMPU)* and other *Remote Terminals*. The cables connect the *TMPU* and the *HMPU* and *Remote Terminals* to the *A bus couplers* and *B bus couplers*. Cables connect to the slip ring so the connection from the *turret* to the *hull* can be made. The cables are routed on different sides of the vehicle to provide redundant capability

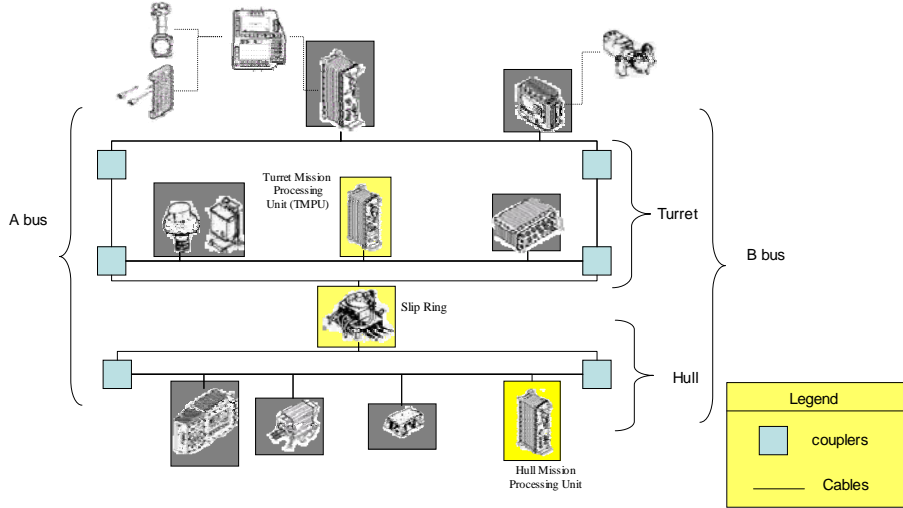


Function: The *Slip Ring* forms the communications link between the two A bus couplers and two B bus couplers which serve the Turret and one A bus coupler and one B bus coupler which serve the Hull.

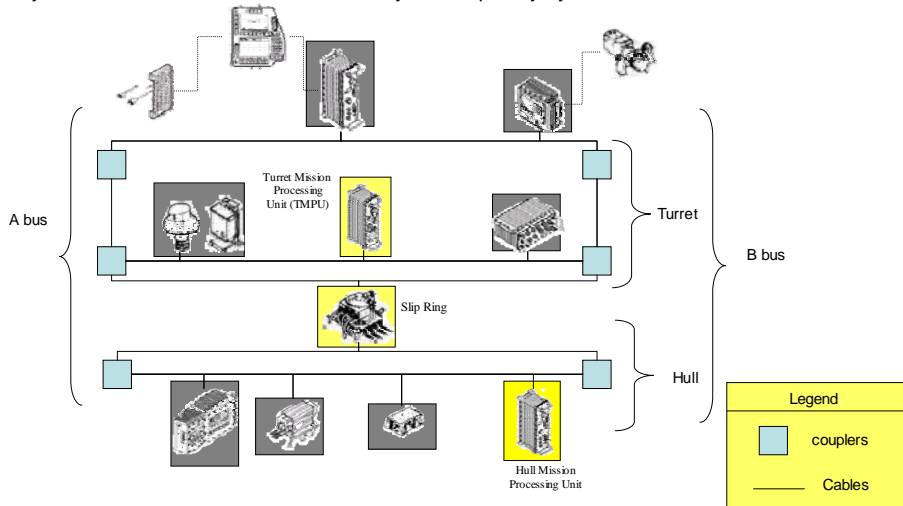


Function: The bus controller is referred to as the *Turret Mission Processing Unit (TMPU)*. It sends and controls the flow of messages across cables through couplers and their cables to remote terminals.

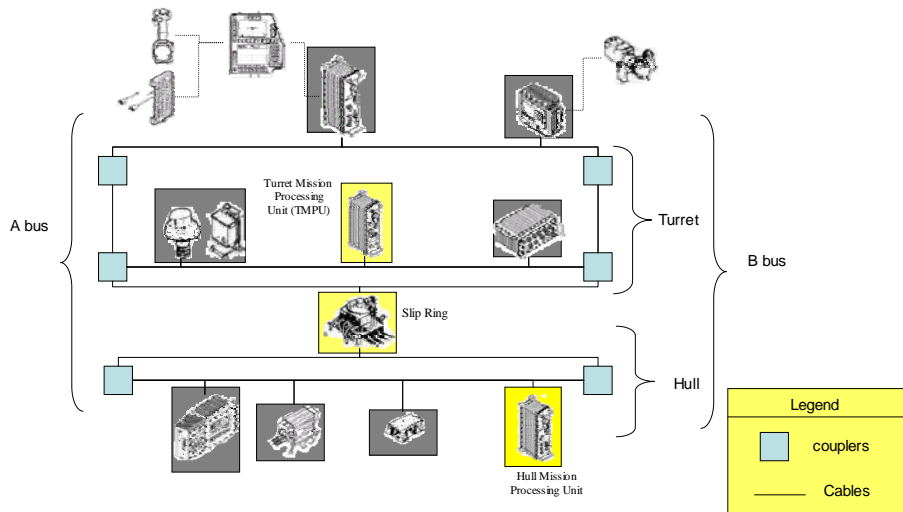
The *TMPU* is also responsible for conducting all system diagnostic checks and for calculating ballistic solutions for the tank under normal operations. These diagnostic and ballistic functions make the *TMPU* like another remote terminal.



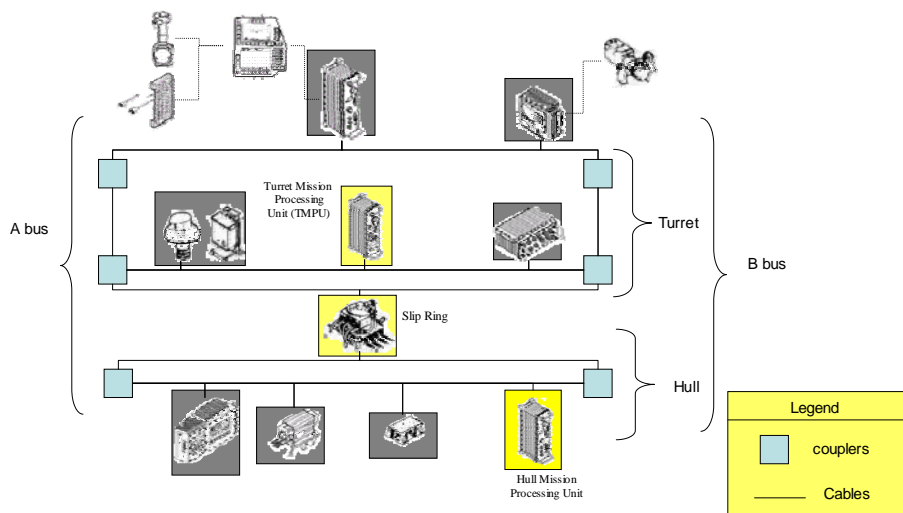
Mechanism: The *TMPU* communicates to *Remote Terminals* through redundant A and B buses. The *TMPU* consists of many computer processors which *control and manage* information transmission throughout the tank Turret systems and the Hull systems by way of cables and couplers. The *TMPU* talks to the *Bus Monitor* referred to as the *Hull Mission Processing Unit (HMPU)* through the A bus and B bus via the slip ring. The *TMPU* by way of the A and B buses can talk to all Remote Terminals, which perform various functions. The *TMPU* can control the talk between any two *Remote Terminals* by way of the A and B buses. Only one terminal can talk to one terminal at a time and the sequence in which any two terminals can talk is established by a fixed priority by the bus controller.



In addition to the *communication and control functions* of the *TMPU*, it also carries out *special functions like other Remote Terminals*. As with other remote terminals it receives and transmits data on the bus in response to bus controller commands. As a *remote terminal it calculates ballistic solutions for the fire control systems and performs system diagnostics*.

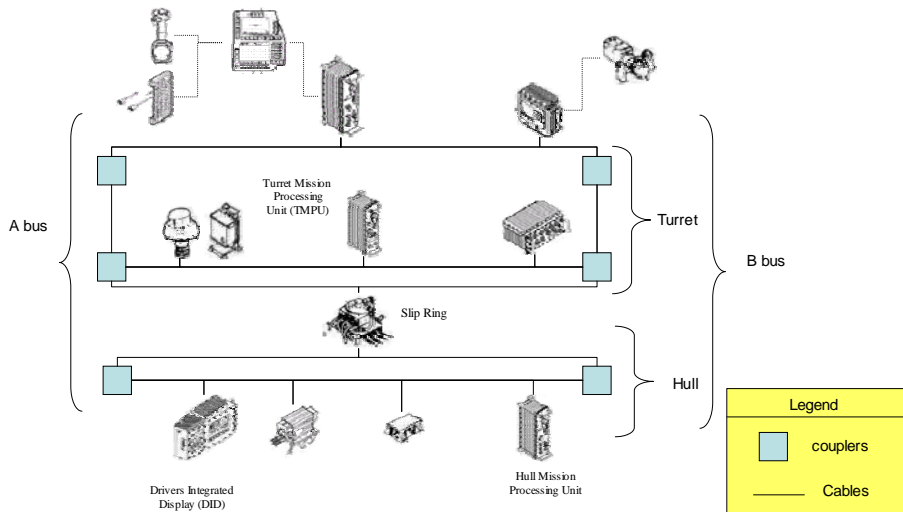


One of the *TMPU's* Remote Terminal functions is calculating ballistic solutions for the Fire Control System. It does this by storing and managing *critical data* such as Boresight data, plumb and sync., scan limits and rate, all drift data, ammo type, all zero data, Commander's Independent Thermal Viewer adjustments, and Sensor inputs for crosswind, cant, lead, ammo temperature and battle-sight range which is then used to *compute solutions for the fire control system employing the processors and the software of the TMPU*.



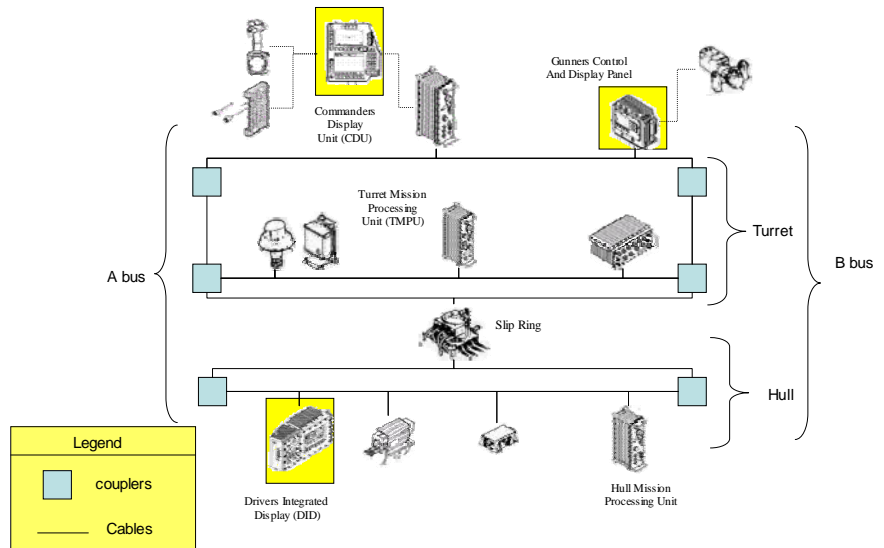
15 Remote Terminal Function of the Turret Mission Processing Unit: Diagnostic Group 1

Another Remote Terminal-like function of the Turret Mission Processing Unit (TMPU) is *diagnosing system components*. There are three different types of test, the *Self-Test (ST)*, the *Built in Test (BIT)* and the *Fault Isolation Test (FIT)*.



16 Remote Terminal Mechanism of the Turret Mission Processing Unit: Self Test Group 1

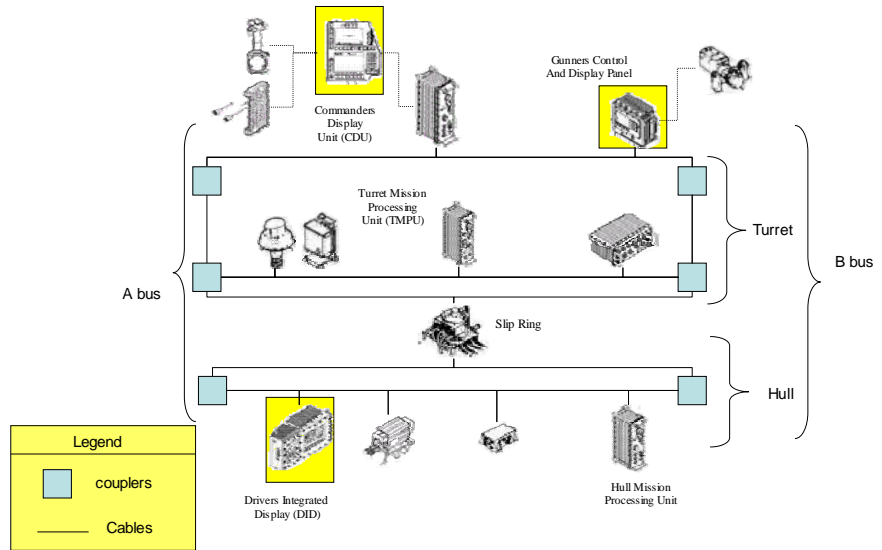
*Self-Test* is designed to run in the background without interfering with normal operations. If a fault is detected by the *Self-Test*, a caution or warning message is displayed in one of three locations; the *Commander's Display Unit*, the *Gunner's Control Display Panel* or the *Driver's Integrated Display*. This is an automatic test and runs constantly in the background.





17 Remote Terminal Mechanism of the Turret Mission Processing Unit: Built In Test Group 1

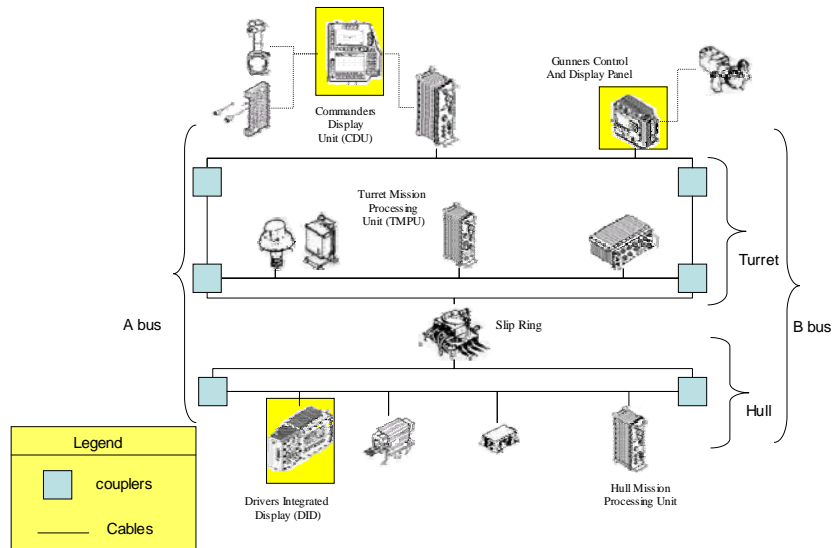
The *Built in Test* is designed to provide extensive and comprehensive test coverage of the component in which the *BIT* is embedded. The *BIT* is an intrusive test which requires components to be shut down. When a fault is detected by *BIT* in its related component, it will display a NOGO message on the *Commander's Display Unit*, the *Gunner's Control Display Panel* or the *Driver's Integrated Display* to alert the crew or mechanic that a fault has occurred



18 Remote Terminal Mechanism of the Turret Mission Processing Unit: Fault Isolation Test Group 1

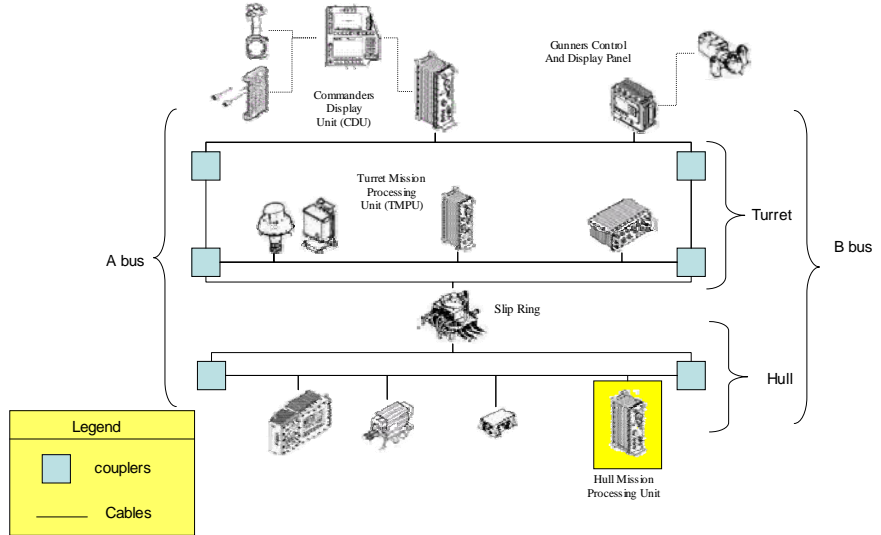
Fault Isolation Test

The *Fault Isolation Test (FIT)* is designed to pinpoint a fault within a group of detected failures or support further testing of the system beyond the capabilities of the *Self-Test* or the *Built-In test*. Maintenance personnel will conduct *FIT* from the *Commander's Display Unit*, the *Gunner's Control Display Panel* or the *Driver's Integrated Display* depending upon the type of fault detected.



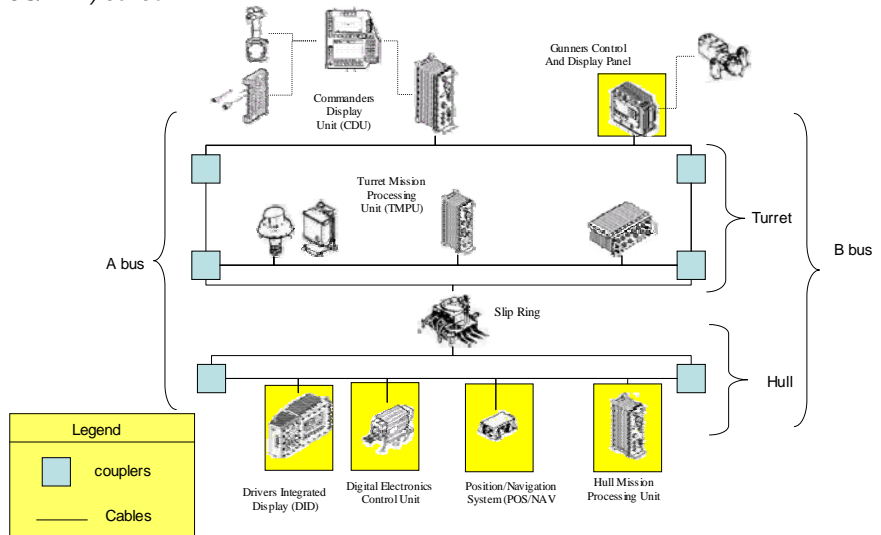
### Bus Monitor/HMPU Function

Function: The *Bus Monitor* or the *Hull Mission Processing Unit (HMPU)* is the *backup* for the *Bus Controller* or *Turret Mission Processing Unit (TMPU)*. If the *TMPU* fails, the *HMPU* can carry out all of the *Bus Controller* functions *except for the use of Global Positioning System information*. Global Positioning System information used for position information is fed directly to the *TMPU* and cannot be accessed by the *HMPU*. *This is the only function which is not dual redundant in the 1553B bus system*. The *HMPU*, like the *TMPU* can send messages across cables through couplers and their cables to remote terminals in the *Hull* and through cables, couplers and the slip ring to the remote terminals in the *turret*.

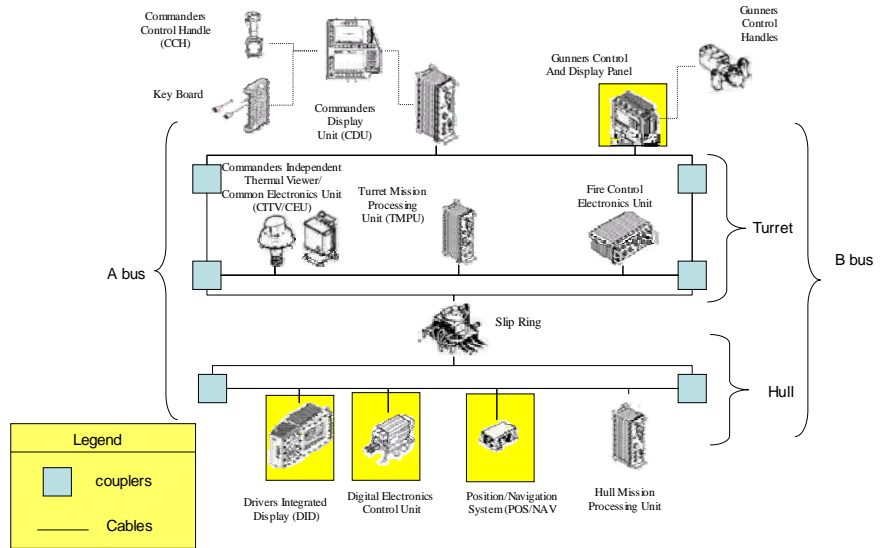


### Bus Monitor/HMPU Mechanism

Mechanism: The *Hull Mission Processing Unit (HMPU)* is also connected to two couplers one on the A bus and one on the B bus in the same way as the *Turret Mission Processing Unit (TMPU)*. This makes up six couplers in all with the addition of the two A and two B bus couplers of the *Turret* system. Three on the A bus and three on the B bus. The other Remote terminals which are connected along with the *HMPU* to these two couplers are: The *Driver's Integrated Display Unit (DID)*, the *Digital Electronics Control Unit (DECU)* and the *Position Navigation (POS/NAV) sensor*.

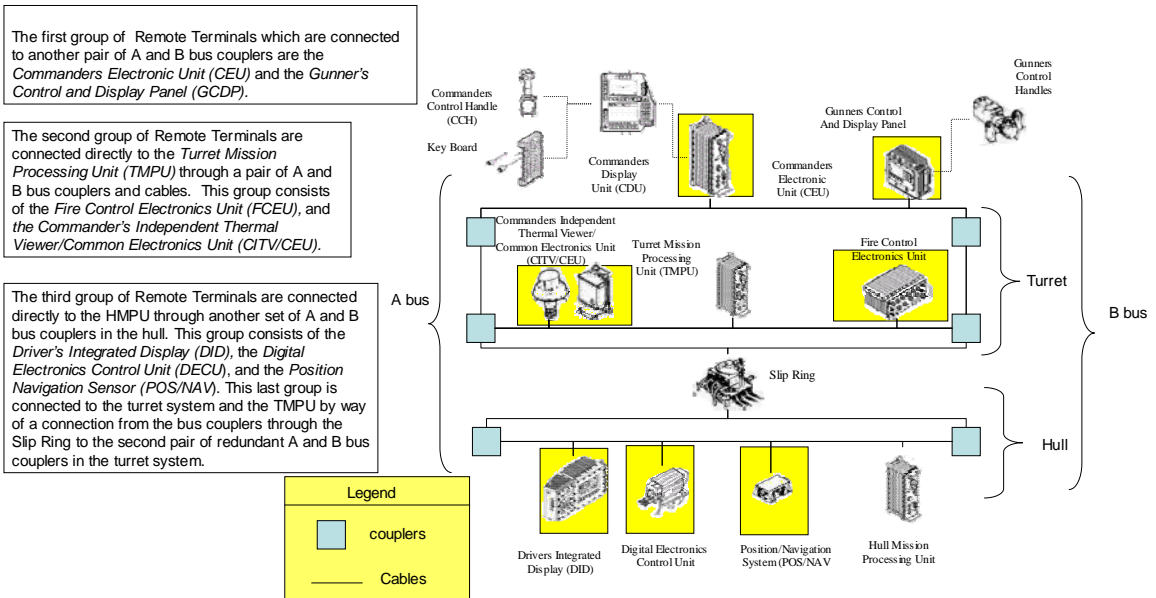


The *Remote Terminals* receive and transmit data on the bus in response to bus controller commands. They are connected to the A and B bus couplers in a specific way, such that, different Remote Terminals are connected to different A and B bus couplers. The couplers in turn are connected to each other on the A and B buses to route all information to the *TMPU* and the *HMPU*.



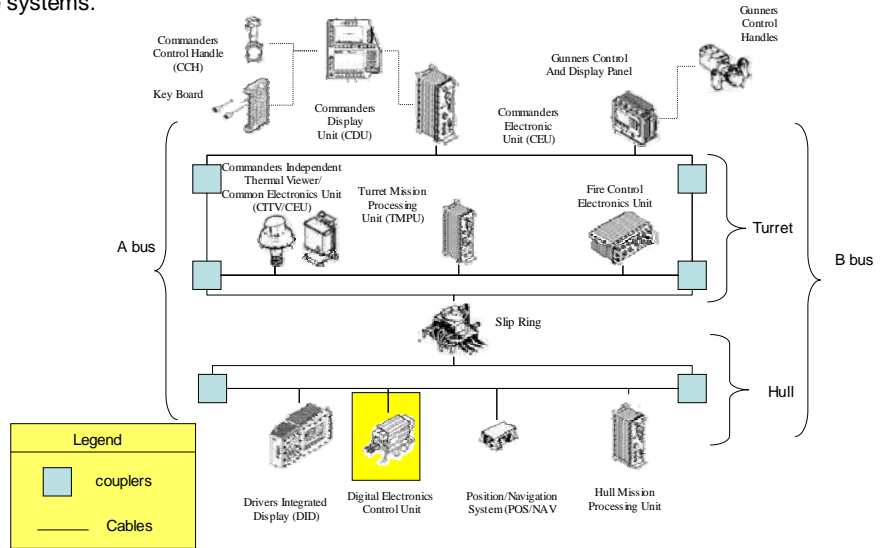
Mechanism of the Remote Terminals: The Remote Terminals are separated into three groups.

Each group of Remote Terminals is connected to a pair of A and B bus couplers.



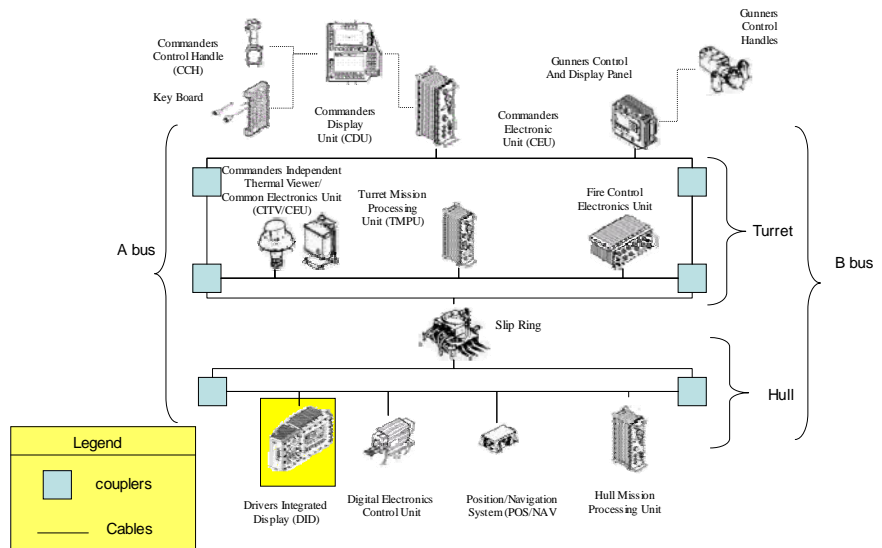
. The Function of the Digital Electronics Control Unit (DECU):

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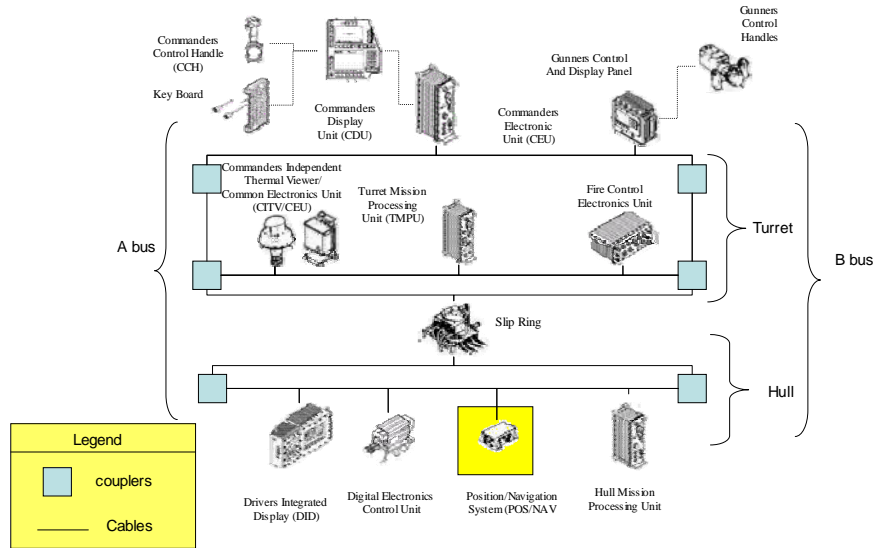
The Function of the *Driver's Integrated Display (DID)*:

The function of the *DID* is to allow the driver access to all automotive related functions and to select back-up functions of the commander's display unit



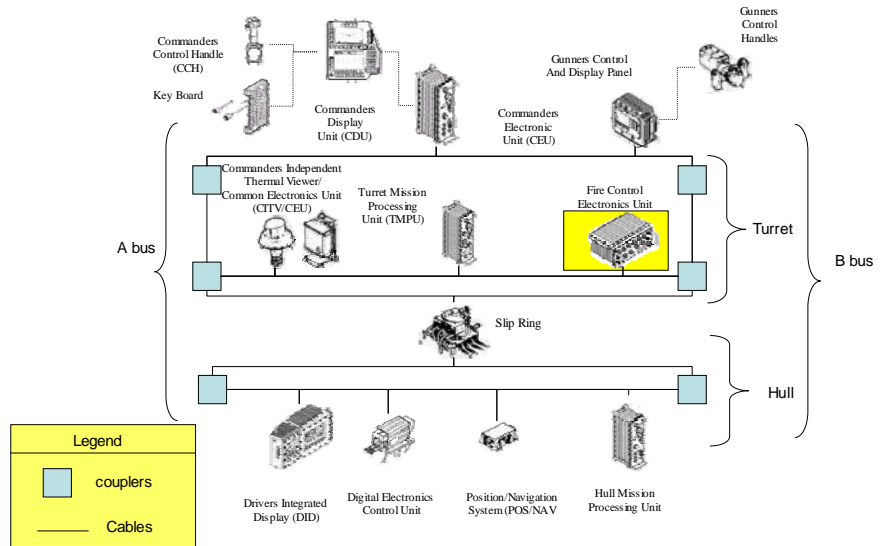
### Remote Terminal Position Navigation Sensor (POS/NAV)

The function of the *Position Navigation Sensor (POS/NAV)* is to provide movement and direction data for the commander, driver and the fire control system. It also provides *dynamic cant for the Fire Control System*.



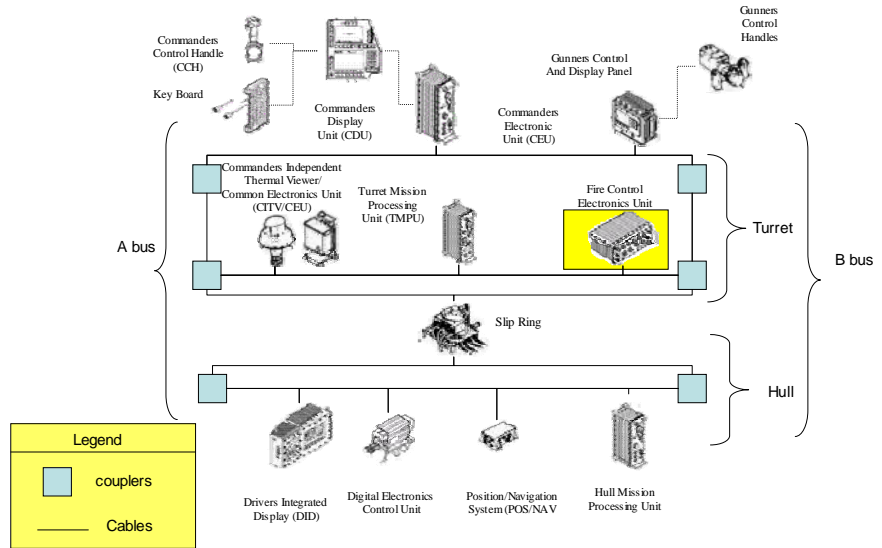
### Remote Terminal Fire Control Electronics Unit (FCEU)

The function of the *Fire Control Electronics Unit (FCEU)* is to integrate the Gunner's Primary Sight with the *Commander's Independent Thermal Viewer*. This allows the Commander to engage a target from the CITV or from the Gunners Primary Sight.



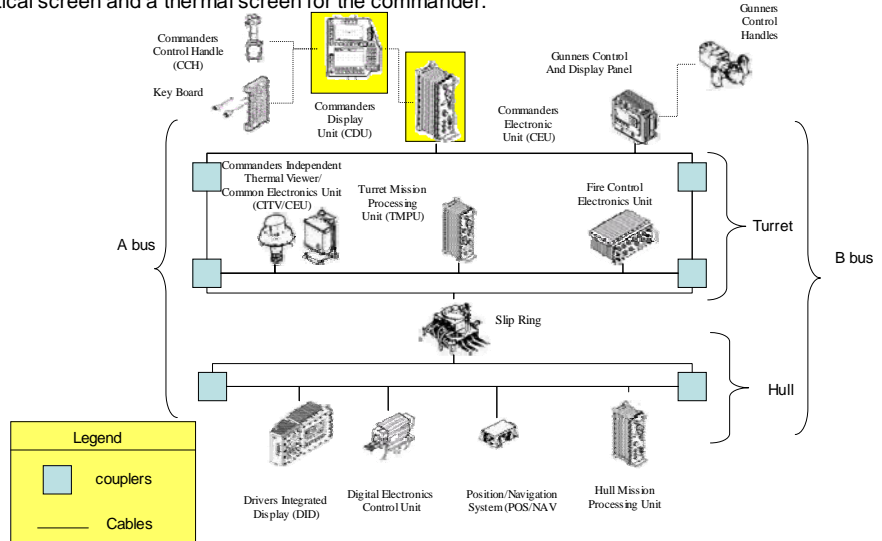
### Remote Terminal Commander's Independent Thermal Viewer/Common Electronics Unit CITV/CEU

The Function of the *Commander's Independent Thermal Viewer/ Common Electronics Unit (CITV/CEU)* is to provide the electronics to give the commander a separate stabilized thermal sight independent of turret movement and the Gunner's Primary Sight. It is independent of the Turret. It can automatically scan or be manually controlled by the commander.



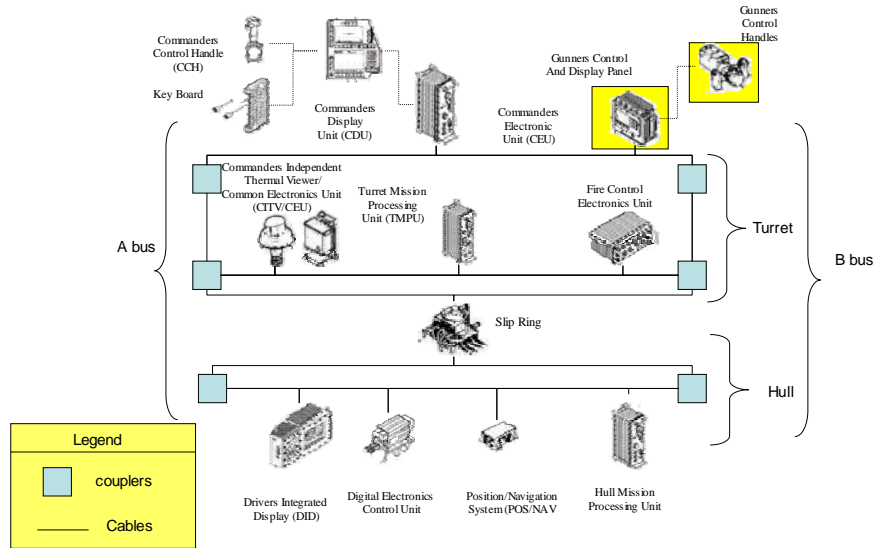
### Remote Terminal Commanders Electronic Unit (CEU)

The *Commanders Electronic Unit CEU* functions to provide the Processing and memory resources for the *Commander's Display Unit* and the command, control and communications functions. It allows for the control of the commander's displays and related databases and serves as the interface to commander controlled inter-vehicular functions like map display server. It also allows interface to common and new tank components and handles passwords, reconfiguration, and radio control through the 1553B bus. It allows operation of vehicle systems and provides a tactical screen and a thermal screen for the commander.



## Remote Terminal Gunners Control and Display Panel (GCDP)

The *Gunnery Control and Display Panel (GCDP)* provides the gunner with access to fire control functions and select backup functions for the commanders display unit. The GCDP converts analog signals from the *Gunner's Control Handles* to digital signals to be transmitted on the 1553B bus.



Now you have finished reading, we wanted you to write your thought about the organization of the curriculum. Imagine that this organization would be given prior to learning for other students, which will assist them in having an overview of the bus system, and direct their learning toward upcoming key elements in the curriculum. The organization should include the following components and functions (listed randomly):

Gunners Control and Display Panel (GCDP)  
Isolate components preventing damage to bus  
Connects remote terminals via A and B bus  
Couplers  
Monitor Engine Systems  
Slip Ring  
1553B data bus  
Carry Information  
Dual Redundant  
A bus and B bus  
Self Test (ST)  
Connects the controller, monitor, and remote terminals  
Commanders Display Unit (CDU)  
Remote Terminals  
Backup Controller  
Bus Controller (TMPU)  
Drivers Integrated Display (DID)  
Bus Monitor (HMPU)  
Connects remote terminals via A and B bus  
Ballistic Solutions  
Priorities for Communication  
Digital Electronics Control Unit (DECU)  
Fault Isolation Test (FIT)  
Converts Analog to Digital Signals  
Cables  
Communicates data  
Built in Test (BIT)  
System Diagnostics



**APPENDIX H: IRB COMMITTEE APPROVAL, INFORMED  
CONSENT FORM, AND STUDENT QUESTIONNAIRE**



Office of Research & Commercialization

September 20, 2006

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3017 Cottage Grove Court  
Orlando, FL 32822

Dear Mr. Wazzan:

The University of Central Florida's Institutional Review Board (IRB) received your protocol IRB #06-3755 entitled "**Cognitive Learning Using Knowledge Construction Interventions.**" The IRB Chair reviewed the study on 9/11/2006 and did not have any concerns with the proposed project. The Chair has indicated that under federal regulations (Category #2, research involving the use of educational tests, survey or interview procedures, or the observation of public behavior, so long as confidentiality is maintained) this research is **exempt** from further review by our IRB, so an approval is not applicable and a renewal within one year is not required.

Please accept our best wishes for the success of your endeavors. Should you have any questions, please do not hesitate to call me at 407-823-2901.

Cordially,

A handwritten signature in cursive script that reads "Joanne Muratori".

Joanne Muratori  
UCF IRB Coordinator  
(IRB00001138, FWA00000351, Exp. 5/13/07)

Copies: IRB File  
Kent Williams, Ph.D.  
Tareq Ahram

JM:jt

## *Informed Consent*

*Please read this consent document carefully before you decide to participate in this study. You must be 18 years of age or older to participate.*

**Project Title:** “Cognitive Learning using Knowledge Construction Interventions”

**Purpose of the research study:** The purpose is to see if the use of elaborative prompts promotes better reasoning and problem solving of computer-based instructional systems. If you agree to participate in this research, you will be one of approximately 80 subjects.

**What you will be asked to do in the study:** If you consent to participate, you will be asked to take a pre-test, and then go through a self-paced presentation. Upon completion, you will be given a post-test. You will be asked to go through the presentation and take the posttest three times. The total time per trial averages from 30 minutes to 45 minutes, with subsequent trials taking less time. You will take a retention test a week later.

**Time Required:** 30 to 45 minutes per trial, total time will not exceed 2 hours.

**Risks:** There are no known risks associated with this experiment. You will not encounter any harmful or explicit material.

**Benefits/Compensation:** The potential benefits of participating in this study include the opportunity to learn about different components of a tank. If you complete this study, you will receive \$20.

**Confidentiality:** Your Identity will be kept confidential. Your information will be assigned a code number. The list connecting your name to this number will be kept locked in the faculty supervisors office. When the study is completed and the data analyzed, the list will be destroyed. Your name will not be used in any report.

**Voluntary participation:** Your participation is voluntary. There is no penalty for not participating.

**Right to withdraw from the study:** You have the right to withdraw from the study at any time without consequence.

**Whom to contact if you have questions about the study:** Wajdi Wazzan, Ph D Candidate, Department of Industrial Engineering and Management Systems, Phone number: (407)277-5566. Dr. Kent W Williams, Faculty Supervisor, Department of Industrial Engineering and Management Systems; Phone number: (407) 823-1094

**Whom to contact about your rights in the study:** Research at the University of Central Florida involving human participants is carried out under the oversight of the Institutional

Review Board (IRB). Questions or concerns about research participants' rights may be directed to UCF Institutional Review Board Office at the University of Central Florida, Office of Research & Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246. The phone numbers are 407-823-2901 or 407-882-2276.

\_\_\_\_\_ I have read the procedure described above.

\_\_\_\_\_ I voluntarily agree to participate in the procedure.

\_\_\_\_\_/\_\_\_\_\_  
Participant Date

\_\_\_\_\_/\_\_\_\_\_  
Principle Investigator Date

**Subject Questionnaire**

Please fill out this form, if you do not qualify for the research this form will be returned to you before you leave the test site

Test Subject # \_\_\_\_\_

Age: \_\_\_\_\_

Department: \_\_\_\_\_

Gender: Male                      Female

Are you a mechanic? Yes No

Have you been trained as a mechanic? Yes No

## **APPENDIX I: TEST AND ANSWERS**

Test Subject #\_\_\_\_ Time Begin\_\_\_\_ Time End\_\_\_\_ Trail\_\_\_\_  
Points Received \_\_\_\_

1. The 1553B data bus performs the following functions
    - A. Communicates data
    - B. Controls and Monitors functions and applications
    - C. Controls and monitors functions only
    - D. A and C
    - E. A and B
    - F. Don't Know
  
  2. The Bus Monitor/ Hull Mission Processing Unit (HMPU) has the following functions under normal conditions?
    - A. Back-up for the bus controller/Turret Mission Processing Unit (TMPU)
    - B. Controls flow of messages
    - C. Access GPS information
    - D. All of the Above
    - E. Only A and C
    - F. Don't Know
  
  3. The mechanism of the 1553b data bus relies on which of the following
    - A. Monitor
    - B. Controller
    - C. A and B bus
    - D. Remote terminals
    - E. All of the Above
    - F. A, C and D
    - G. Don't Know
  
  4. If Digital Electronics Control Unit (DECU) is not functioning what remote terminal is affected?
- 
-

5. The A bus and B bus

- A. Is dual redundant
- B. Controls the flow of information
- C. Connects the controller, monitor and remote terminals
- D. All of the Above
- E. A and C
- F. Don't Know

6. If the A bus cable in the hull were damaged what components would be affected?

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7. Bus couplers perform the following functions

- A. Distribute data and messages
- B. Connect the remote terminals via A and B bus cables
- C. Isolate all the components to prevent damage to the main bus
- D. All of the Above
- E. C and B
- F. Don't Know

8. The Bus Controller has been damaged what functions would be interrupted?

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9. Bus cables

- A. Carry all information between components
- B. Are not dual redundant
- C. Connect directly from controller to remote terminals
- D. All of the Above
- E. A and C
- F. Don't Know

10. The connection between the Hull Mission Processor Unit and the Turret Mission Processor Unit has failed what are the possible components that have failed

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11. The Drivers Integrated Display is not reporting engine status. List the components that might have failed

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12. Describe the Functions that the Hull Mission Processor Unit Performs during emergency condition (TMPU failure)?

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13. During BIT testing you find out that the Position Navigation System is not providing accurate position data what device(s) is (are) malfunctioning?

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14. Fault Management system level diagnostics consist of what test(s)

- A. Self Test (ST)
- B. Built In Test (BIT)
- C. Fault Isolation Test (FIT)
- D. All of the Above
- E. Only A and B
- F. Don't Know

15. The system appears to be functioning correctly, diagnostics, fire control are operational, but you are unable to update global positioning system. What device is performing the diagnostic and ballistic solutions?

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16. To determine the exact fault what level of test is performed (check all that apply)?

- A. Self Test (ST)
- B. Built In Test (BIT)
- C. Fault Isolation Test (FIT)
- D. All of the Above
- E. Only A and B
- F. Don't Know

17. T MPU fails what functions are affected and what component assumes the role of Bus Controller?

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18. \*The 1553b data bus would fail under what circumstances?

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19. Remote terminal functions are?

- A. Serve as back up to the controller and monitor
- B. Respond to the bus controller
- C. Receive and transmit data
- D. All of the Above
- E. Only C and B
- F. Don't Know

20. The Fire Control Electronics Unit (FCEU) is malfunctioning what devices are not working properly?

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21. Digital Electronics Control Unit (DECU) performs the following functions

- A. Serves as a backup to the HMPU
- B. Converts analog to digital signals
- C. Provides control and monitoring of engine systems
- D. All of the Above
- E. Only B and C
- F. Don't Know

22. The Commanders Display Unit is not working properly, what remote terminal could be malfunctioning?

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23. What is the mechanism for the Turret Mission Processing Unit (TMPU)/ Bus Controller?

- A. Communicates via the A and the B bus
- B. Communicates to all Remote Terminals
- C. Communicates with remote terminal simultaneously
- D. Establish priorities for communication among any two remote terminals
- E. All of the Above
- F. Only A ,B and D
- G. Don't Know

24. Upon completion of the Fault Isolation Test (FIT) you are told that communication with the hull has been severed what components would you check?

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25. When presented with a malfunction what components can be used to access diagnostics by the crew and the mechanic?

- A. Gunners Control and Display Panel (GCDP)
- B. Drivers Integrated Display (DID)
- C. Commanders Display Unit (CDU)
- D. All of the Above
- E. Only B and C
- F. Don't Know

26. Inability to get a ballistic solution would be the result of the failure of what components?

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27. The Fault Isolation Test is initiated by?

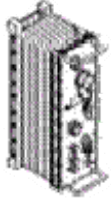
- A. Operator
- B. Mechanic
- C. Done automatically by the tank
- D. All of the Above
- E. Only A and B
- F. Don't Know

28. What functions does the Turret Mission Processing Unit (TMPU) perform?

- A. Controls flow of messages
- B. System diagnostics
- C. Calculates ballistic solutions
- D. All of the Above
- E. Only A and C
- F. Don't Know

29. Given the following components of the 1553b data bus draw the architecture on the next page. Use the numbers to represent the components and lines to represent cables. If needed components may be used several times.

Commanders Electronic Unit (CEU)



1

Gunners Control And Display Panel (GCDP)



2

Hull Mission Processing Unit (HMPU)



3

Turret Mission Processing Unit (TMPU)



4

Digital Electronics Control Unit (DECU)



5

Position/Navigation System (POS/NAV)



6

Commanders Independent Thermal viewer/Common Electronics Unit (CITV/CEU)



10

Drivers Integrated Display (DID)



9

Fire Control Electronics Unit (FCEU)



7

Coupler



11

Commanders Display Unit (CDU)



12

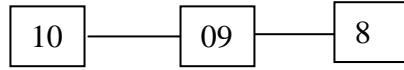
Slip Ring



8

Draw Picture the of the 1553b Architecture

Example



30. Describe the connections between the different components and the couplers?

Answer Key

Question	Answer	Scoring Matrix
1	E	1
2	A	1
3	E	1
4	DID	1
5	E	1
6	None, the B bus would still be able to pass information	1
7	D	1
8	GPS	1
9	A	1
10	Cables, Couplers Slip Ring	1=.25, 2=.75, 3 = 1
11	DECU, Cables, Couplers, TMPU or HMPU DECU=.5 Cables=.25 Couplers=.25 TMPU or HMPU = .25 MAX pt 1	1
12	Same functions as TMPU except GPS If answer all functions of TMPU =0 TMPU or Functions = .5	1
13	TMPU = .5 Cables or couplers= .25 Slipring=.25	
14	D	1
15	HMPU	1
16	C	1
17	GPS= .5 HMPU = .5	
18	A and B =.75 TMPU and HMPU = .75 both answers = 1	1
19	E	
20	TMPU .5 CITV .25	1
21	E	1
22	CEU	1
23	F	1
24	The Slipring, cables and couplers Slipring= .50 Cables=.25 couplers= .25	1
25	D	1
26	The TMPU and HMPU, GCDP, FCEU, POS/NAV TMPU and HMPU = 1 if any other.25 TMPU=.25 or	1

Question	Answer	Scoring Matrix
	HMPU=.25	
27	B	1
28	D	1
29	<p>All components in the right spot with correct number of couplers and connections correct = 2pnt</p> <p>Components no couplers or couplers in wrong location 1pts</p> <p>Missing components but correct connections =.25 pts</p> <p>Locations of any components in the wrong location i.e. in the hull suppose to be turret = 0</p>	2
30	<p>Describes that couplers are connected to each component and that it is dual redundant states the connection between the hull and turret through the slip ring = 2 pts</p>	2

Note: Inference question are annotated with an asterisk on the test



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