Innovative Debriefing Solutions to Enhance Fighter Pilot Training

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ABSTRACT

Debriefing is a crucial aspect of pilot training. To enhance the effectiveness of fighter pilot training, TNO Defence, Security and Safety and the Royal Netherlands Air Force (RNLAF) have developed various novel debriefing concepts. In typical mission debriefings, large amounts of data are recorded, often from different sources such as on-board systems and sensors. However, the available time for processing and debriefing this information and relating it to mission-specific or user-specific learning objectives is limited. This provides challenges for data integration, synchronization and presentation, and requires solutions to provide users with the right information at the right time in the right format. Instead of replicating information in exactly the same manner as presented in on-board systems we propose alternate information modes which provide operational users with additional cues. In this paper we discuss the results of our work on IDEFIX, our innovative debriefing environment. Together with operators we developed a number of solutions for presenting information in an adaptive, user-centric and mission-specific manner. IDEFIX has a dynamic Graphical User Interface that allows the user to customize the debriefing environment. Mission type specific parameters and objectives are used as input to control the presentation of information into different views and panels. A new agent-controlled, context-dependent 3d-view was created to enhance situational awareness and to gain insight into fighter jet movements, threats and weapons impact. IDEFIX proves to be a useful environment for testing integral plan/brief/debrief capabilities, which will be the focus of our future research.

ABOUT THE AUTHORS

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Ronald van Maarseveen joined TNO Defence, Security and Safety in 1998. He has developed satellite SAR processors and has researched the extraction of environmental parameters using navigation radars. Currently, he's performing research on UAV sensor simulations and virtual environments. Before joining TNO, he has worked for five years researching 3D planning capabilities for electromagnetic deep hyperthermia. Ronald holds an MSc in Experimental Physics with a specialization in computational science.

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INTRODUCTION

Debriefing plays a crucial role in the training process of fighter pilots, enhancing the effectiveness of live and/or virtual mission training significantly. In our research, we have investigated a number of solutions to improve the presentation and elaboration of mission debriefings in an innovative manner that is both mission-specific and user-centric. These solutions have been developed in close co-operation with operational users and domain experts and have been integrated in IDEFIX, our test bed for debrief solutions.

As a first solution, an information-augmented timeline has been developed. The timeline can be used to provide a quick and intuitive overview of the events that have occurred during the mission execution compared to the mission's planning. The second solution is the use of so-called conceptual views that can be utilized to view and present mission data in a manner that is adaptive to the mission type, events in the mission, objectives and user preferences. The conceptual views utilize a 3D viewer that can augment the virtual environment with additional information overlays, an automated system for controlling positioning and orientation of the 3D viewer, and the possibility to show recorded video data in a relevant manner. To support conceptual views, the next solution is an analyzer that extracts relevant information from mission data. As a last solution, we have implemented the option to have the user control the amount of information that is presented and the manner in which information is presented.

This paper, first, describes the main problem areas that we distinguish for existing debriefing systems. Subsequently, our solutions and followed research method are described in detail. As a conclusion, we look forward and describe the possible future enhancements and applications for IDEFIX.

DEBRIEFING ENHANCEMENT

Debriefing plays a key role in the preparation and training of fighter pilots. Almost every mission involves hours of training to prepare for the "real thing". After each mission, the debriefing is the very first moment in which pilots have the opportunity, to analyse and review their mission performance and results together. It is during the debriefing that pilots, aided by technological means, can replay the recorded data of the mission, compare it with the planning and the mission objectives, and learn and identify most of the lessons. As such, debriefings, or mission evaluations play a crucial role in obtaining and identifying the lessons learned out of each mission,

The effectiveness and the efficiency of debriefings, however, is affected by various problems such as limited amount of time available for debriefings, information overload due to an increasing amount of available data, and simply not transforming existing data from the operational platform into useful (analysis and debriefing) information. Within the wide range of possible solutions we distinguish three main areas of improvement for the next generation debriefing systems (Jacobs et al., 2006).

The first area of improvement is the *standardization* of debriefing data exchange. This is important for two main reasons: First, to enable the use of the same debriefing systems for both live and simulated mission training events, and second, to facilitate the debriefing in joint and/or combined operations where different debriefing tools are brought in by the various participants. Standardization is also one of the necessary steps towards an integrated approach of the entire mission, where initial planning and briefing are aided by the same tools as the one used for debriefing. An integrated set of tools for planning, briefing, and debriefing will improve the effectivity and efficiency of the entire mission and facilitate the learning process of pilots during the debriefings considerably.

Currently, the Simulation Interoperability Standards Organization Distributed Debrief Control Protocol Study Group (http://www.sisostds.org) is investigating and working on a new standard for controlling a distribution of debriefing systems, possibly on different sites, in a unified manner (Pitz and Armstrong, 2006). This is a potential solution for the data exchange problem. TNO, currently, investigates the DDCP protocol and has an interest in joining this SISO standardization activity.

The second area of improvement is *data fusion* and *data enhancement*. These principles can be utilized to avoid user information overload and lead towards a more effective use of mission data. Data fusion and enhancement is a challenge faced not only in our research on debrief solutions Within TNO, several research teams have started projects for the development of tools that improve some aspects of this problem. The combination of the resulting development can be a very powerful one when applied to debriefing systems. We decided to work together with some of these projects to address data fusion and enhancement issues.

One of these projects is called GRACE (Generic Reconstruction and Analysis Computing Environment), a generic reconstruction and analysis tool. Based on the plug-in concept, GRACE is capable of reading many input formats, synchronize them, and send them to several output plug-ins. It is also possible to use context independent analysis plug-ins to elaborate the data.

A second project is called JANIS (JROADS Adaptive Network Interpretation Suite), which, similar to GRACE, is a plug-in based tool for the exchange of data between many application using network protocols such as DIS (IEEE, 1998), HLA (IEEE, 2000) and Link-16 (North Atlantic Treaty Organization, 2006). In JANIS it is possible to plug-in new modules that extend the communication capabilities of software tools, independently from the programming language in which they are written, and also implement new communication protocols.

The third improvement area is to develop *mission-specific* and *user-centric* debriefing solutions. Missions, and consequently also debriefings, can be performed at different training levels, from team level (two pilots) up to collective level (hundreds of participants). The requirements for a debriefing at team level are very different from the one at collective level: each type of mission requires, for example, a different set of views and relevant data, and also the elaboration of data into information differs. Also, each user has his/her own learning style, needs, habits, and preferences. This requires a certain flexibility of the system in changing, saving and re-using the interface layout, settings, and preferences chosen in previous sessions.

(Jensen et al., 2006) describe a toolset that is based around a timeline that is augmented with mission event representations. In this toolset, automated analysis of voice communications is performed to extract interesting events during the executed mission.
It can be concluded that enhancing the effectiveness of mission debriefings and the efficiency of debriefing systems are important factors in improving the training of fighter pilots. In this paper, we will further focus on the development of several software components that improve mission debriefings in the third identified improvement area, and are addressing the need for mission-specific and user-centric debriefing solutions.

IDEFIX DEVELOPMENT

Our research started in 2006 with an operational task analysis (OTA) at the 323 squadron of the Royal Netherlands Air Force (RNLAF) in combination with a survey of available (F-16) debriefing systems. As a result of these two activities, we developed a list with potential solutions and/or improvements of debriefing systems. From this list, a number of novel concepts were derived that formed the basis for the development of the IDEFIX test bed. IDEFIX is the Innovative Debrief Environment in which we investigate and "FIX" the various debriefing challenges (Jacobs, et.al., 2006).

In our research we have focused mainly on the development and testing of a number of solutions for presenting information in an adaptive, user-centric and mission-specific manner. This research has been performed in close co-operation with actual debrief system users.

The IDEFIX development team consists of specialists in multiple areas such as software engineering, training and human factors. Several existing software components that have been developed within our institute have been re-used and extended in IDEFIX. One example is EVE (Enhanced Virtual Environment), a data-driven and data-centric framework based on a modular architecture for rapid prototyping of 3D simulation environments.

We used an iterative method to develop and improve IDEFIX, which resembles a typical Agile System Development Lifecycle (Agile Alliance, 2001). The lifecycle consists of three parts (see Figure 1): a list with innovative ideas (Item list) is created at first, and is continuously updated during the process. The items from the list with the highest priority are then developed, and the newly developed software is presented, reviewed and discussed by different groups of people, such as developers, users, and domain experts. This development cycle requires a close collaboration with our stakeholders, which represent a broad array of disciplines, including fighter pilots, operators, and mission support personnel. Apart from frequent feedback moments, two workshops have been held to review intermediate results and to discuss and update (new) features and requirements.

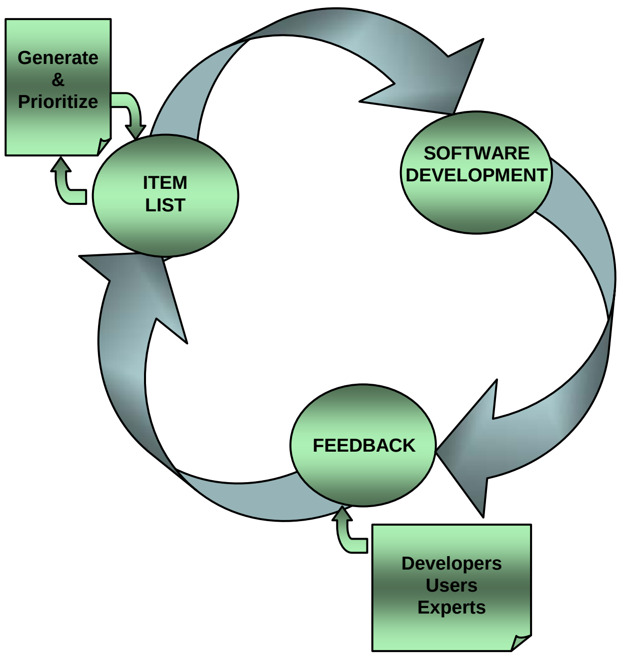

Figure 1. IDEFIX development method

Throughout the project, flight simulator data extracted from Airbook© (http://www.simigon.com), a pc-based training environment for fighter pilots used by the RNLAF, has been used consistently as main test data input for IDEFIX. The data represents relevant operational cases or reference missions for developing and analyzing our novel debriefing solutions. This, according to our experience, helped in detecting and analysing real problem areas further. From this, conclusions and solutions can be easily translated into live mission data analysis and debriefings.

OUR SOLUTIONS

For the development of IDEFIX, our main focus was on providing means to present the right information in the right format at the right time. This requires solutions that are adaptive with respect to the mission, the specific events that occur during the mission, both mission and training objectives, and the user's personal preferences.

The solutions we developed are:

1) a timeline-based mission navigation tool that provides quick and effective insight in the events that have occurred during the mission;

2) conceptual views that provide context-dependent information enhancement, representation and visualization;

3) a debrief data analyzer that provides feedback to the user based on specified mission objectives. The results are used to select suitable conceptual views for viewing specific parts of a mission;

4) the ability to have the user control the amount and types of information and its presentation.

MISSION OVERVIEW AND NAVIGATION

As a first solution, an information-augmented mission timeline was developed. The mission timeline provides a quick and clear overview of the entire mission and the key events that have occurred. The timeline view provides the possibility to jump to specific events or time stamps.

To increase the efficiency of the debriefing, we use a colour gradient to provide the user with an indication of the (relative) importance of various mission phases. This indication is mainly based on logged events, but also on the amount of communications between units and the aircraft's manoeuvres. The colour gradient provides an instantaneous indication of which parts of the mission are most relevant and which parts are less eventful.

Event markers are placed automatically on the timeline as indicators of the most important or relevant events based on data analysis. Typical events are common ones such as an aircraft take-off and landing, but also mission-specific events such as the initiation of a bombing run, and the moment of bomb impact for an air-to-ground mission or the start of a dog fight during an air-to-air mission. Other examples of events that are supported are: radar detections, weapon locks, and aircraft manoeuvres that cause exerted g-loads which exceed a certain limit.

Besides automatic event marker placement, the system also allows the user to place user-defined markers on the timeline in order to bookmark certain moments in time or to stress certain events in the mission that have not been detected by automatic analysis. Our stakeholders identified the need to manually add markers both during the execution phase, and during the debriefing, and both in a live and in a simulation environment.

The event markers are not merely indications of events. By clicking on an event marker, it is possible to jump forward or backward in the mission and replay it from the designated point. To achieve this, accurate synchronization of all presented data is required.

CONTEXT-DRIVEN CONCEPTUAL VIEWS

To present data to the user, we have developed so-called conceptual views. Conceptual views are context-specific descriptions of 1) what selection of data is presented and 2) the manner in which the data is presented. Enabled by analysis of logged data based on mission objectives, instances of conceptual views can be assigned to specific time slots of the mission, i.e. certain phases of the mission. Examples of events during the mission that are represented by a view instance are: A bomb run, a dog fight or simply the event of nothing interesting happening at all.

To support conceptual views, a number of features have been implemented in IDEFIX that together can make up a conceptual view. These features are:

1) a 3D mission visualization feature that is able to augment the 3D view with additional data in the form of 3D graphics overlays, such as entity trajectories and weapon impact visualizations;

2) a system that controls positioning and movement of the 3D viewer, thereby enhancing situation awareness and providing insight into events of interest;

3) a “smart” video player for showing a selection of streams of video imagery, based on their relevance for a certain mission and events that occur;

A single conceptual view thereby consists of context-specific instances of the 3D viewer with any chosen data augmentations and the 3D view controller and a selection of video streams to show.

In the next sections, these three features are elaborated in more detail.

Augmented 3D viewing capability

We believe that, to intuitively and efficiently present information, a graphical solution is required. For this purpose, we have integrated a 3D visualization functionality into IDEFIX, which is enhanced with additional information in the form of so-called 3D graphics overlays.

The 3D viewer offers basic functionality in the form of mission area visualization and the visualization of any entities operating within. Entities can be enlarged for the purpose of visibility. The 3D viewer allows the user to navigate within the virtual environment in an intuitive manner, closely resembling user navigation in the commonly used Google Earth viewer.

The 3D viewer features 3D graphics overlays to represent additional information. Based on mission objectives and user preferences, the overlays can be displayed. Overlays are only displayed during the time that they are considered relevant with respect to mission objectives and to the events that actually occur during the mission execution in relation to these objectives, thereby keeping the information load to a minimum.

The following three IDEFIX graphics overlays can be seen as examples of context-driven conceptual overviews. These lead towards augmented information presentation on one hand, and preventing the user from information overload on the other hand.

Entity trail

An entity “ribbon trail”, representing an entity’s movement history up to the current point in time, can be visualized in order to provide the user with insight into aircraft and projectile flight trajectories.

The colour of the entity trail can be used as a means of displaying quantitative information. For example, the g-forces that are exerted upon aircrafts and pilots can be visualized in the entity trails. By adjusting the colour (on a scale from blue to red), the user can identify the relative amount of g-force exerted, and where during the mission it exceeds a certain set limit (see Figure 2).

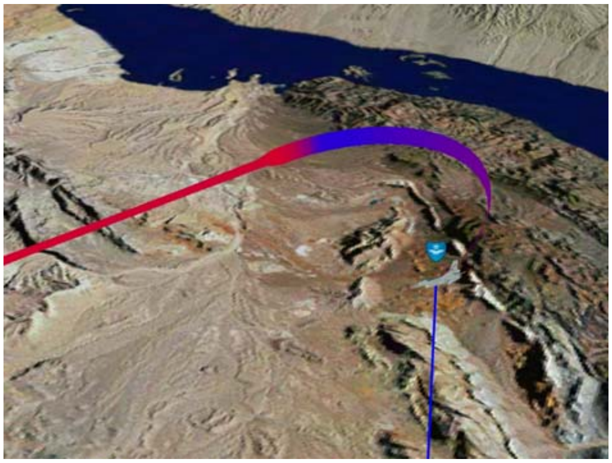

Figure 2. G-load visualization

Projectile trajectories
The visualization of projectile trajectories and their predicted area of impact can provide useful feedback for analysis of a bomb delivery, e.g. the aircraft's position and orientation at the point of weapon release or the probability of hitting the designated target (see Figure 3).

Figure 3. Bomb trajectory visualization

Bomb fragmentation envelopes
The 3D view is, in this example, augmented by an overlay that visualizes the fragmentation envelopes of bombs that have hit the ground. After impact, a dynamic fragmentation envelope is drawn (see Figure 4). This allows for evaluation of the pilot's escape manoeuvre and the impact of the projectile, also enabling blue ground forces to assess safety/ no-go zones. Currently, we use a simple, rule-based model for simulating the fragmenation envelope's shape. However, more detailed physics-based models can be inserted as a plug-in.

Figure 4. Bomb fragmentation envelope visualization

Besides manual navigation, the 3D viewer additionally features a novel computer-controlled system for positioning and orienting the user's viewpoint.

Computer-controlled 3D views
When using a 3D viewing application, it is often difficult to achieve and maintain a viewpoint that is satisfactory in terms of the information that is visible on screen and the perception of spatial cues. Besides that, manually controlling the viewer can be a tedious and distracting task, especially when observing highly dynamic situations from an up-close perspective. To assist in resolving these issues, we added the so-called "camera director" functionality to the 3D viewer.

The camera director (Van Son, 2005) is a system used for controlling movement and positioning of the view or "the camera" in a three-dimensional viewing application. The camera director is designed to enable automatic, computer-controlled viewing of entities (static or moving objects in the environment) while subjecting to certain constraints or view descriptors. The camera director not only relieves the operator from a serious amount of manual work controlling the 3D view, but also generates views that provide a good manner of displaying certain information with respect to the user's situation awareness and certain training objectives.

Each timestep, the camera director calculates the optimal view position and orientation, given the current state (position, movement direction and speed) of the entities of interest in the environment (see Figure 5).

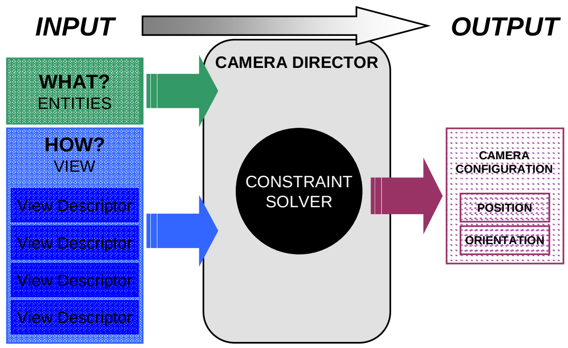

Figure 5. Camera Director overview

The camera director uses a set of entities and combination of view descriptors as input. View descriptors are objects that can be combined to describe a view, and can be parameterized. Examples of view descriptors are "look at entities from a certain angle α" or "keep all specified entities in view".

Given certain entities and view descriptors as input, the camera director utilizes a constraint solving mechanism to dynamically determine the optimal camera position and orientation. View descriptors are solved using abstract cinematographic reasoning concepts such as the point of interest or the line of interest in a particular scene.

The camera director is used to calculate different views based on the events that occur. Examples of used views are an overview for keeping all entities in the field of view from a top-down perspective and a bomb run view, maintaining a perfect 90-degree side view on the aircraft and, optionally, the projectile and the designated target.

Smart Video Images

During a mission it is quite common to record video images in the cockpit. The most common recorded images are: left and right MFD's (Multi Functional Display), HUD (Head-Up Display), and RWR (Radar Warning Receiver). In most debriefing systems it is possible to synchronize and replay the recorded video images. However, these images do not always add useful information, and increase the risk of causing information overload or distracting users from more relevant information in the case of continuously presenting these images during the debriefings.

Our system can show up to 16 synchronized videos, organized in a sizeable tabular panel. Based on the type of mission, the system can suggest the user which kind of images are important on which moment: for example when the system detects enemy radar emissions, then it shows the user that the RWR images might be important to look at. Although the system suggests the best view for the specific moment of the mission, it is up to the user to decide whether to accept the system's proposal, and to switch to a different video panel or view.

DATA ANALYSIS AND FEEDBACK

So far, we presented solutions for the visualization of data, by means of our conceptual views. The displayed data, however, is not the raw data produced by the simulator or the real aircraft, but needs to be enhanced by means of analysis.

Based on the type of mission and the objectives defined prior to the mission, analysis determines if the objectives have been met. Although objectives exist in a wide variety, for debriefing system enhancement we focus mainly on those objectives that can be measured and automatically detected by the system. Examples are: a constraint not to pass under the mission's hard deck at a certain level, to stay clear of bomb fragmentation envelopes or to limit the G-Load to a predefined maximum. This allows experts who are conducting the analysis and debriefing to focus more on those areas where (human) expertise is pivotal to make a solid assessment of a complex situation in a mission or to evaluate a mission in area's where computers simply can't. An example of this would be the semantic analysis of voice communications (Pitz, 2006).

We developed a GUI panel where it is possible to specify and set the objectives for a specific mission. As a result of the analysis, specific conceptual views are created and timeline markers are generated to indicate whether certain objectives are met or violated. For example, a hard deck violation is displayed as 3D graphics overlays, e.g. a change of colour of the subject entity, or 3D markers along the trajectory of an entity, and results also in (a maximum of) two timeline markers being drawn: one for going below the hard deck and one for coming back above, defining a hard deck violation interval along the timeline.

INFORMATION FLOW CONTROL

The solutions that have been presented so far are focused on providing useful information based on the type of mission that is debriefed, events that occur and mission or training objectives. However, we stress the point that this information needs not be forced upon the user. Instead, the user should be able to control the amount and type of information, as well as the layout of the presentation, at all time.

Therefore, we implemented the possibility to control the information flow at runtime, switching pieces of information on or off, and also switching between different conceptual views is always presented as an option and is not performed without the user's consent.

The layout and user-friendliness of a software tool also depends on the personal preferences of the user. We tried to meet the user's personal needs by designing an adaptive GUI: at runtime, it is possible to manage the size and the position of every single component by mouse drag, and the settings and preferences can be saved in a user-defined profile that can be re-used in sessions.

To maximize the use of the available space on the screen the components are integrated in re-sizeable tabular panels, in order to be able to switch very easily between the different available views. We also chose a minimalistic layout of the components, with very thin borders and window elements so that the space is filled with useful information.

Besides controlling information at runtime, IDEFIX also allows the user to create and to modify conceptual views offline using XML-based configuration files.

RESULTS AND CONCLUSIONS

We have described a number of solutions for improving the effectiveness and efficiency of fighter pilot debriefings. These solutions have been implemented in IDEFIX, our debriefing solutions test bed, and focus on providing a mission-specific and user-centric debriefing approach.

Since our iterative development approach contained many feedback moments with our stakeholders, we have reason to believe that the implemented solutions can be an improvement for debriefing systems and can already benefit the debriefing of the specific missions we used as reference missions during development and testing of our novel solutions.

One of the most important challenges that remains is to determine the right trade-off between simply supporting the debriefing process with novel system solutions and going as far as replacing domain experts by automatic analysis. It is shown that certain analysis tasks can already be performed by a debriefing system, but conversely, other analysis tasks are very context-dependent and hard to realize in a correct manner without human expertise. Therefore, complementary solutions should be pursued.

Another challenge that needs to be resolved is the issue of using classified data in varying debriefing environments. Certain data, both from the live platform and the simulator, can be too classified to be exported to a debriefing system, thus limiting the use of the debriefing systems to restricted areas only. This issue becomes even more relevant to address for debriefing of combined and/or joint operations, when different nations are operating together, and data needs to be exchanged for a correlated and combined view of a mission.

WAY AHEAD

As stated in the previous section, currently, our solutions have focused mainly on improving debriefing in a mission-specific and user-centric manner.

For the near future, we will continue with the development of new solutions in IDEFIX based on the agile system development approach and consequently re-iterating the list with possible solutions. We will focus more on the challenges faced by other types of missions, and thus expand the capabilities of the system.

The RNLAF will use the gathered knowledge in this research for the specification of requirements of future debriefing capabilities for the F-16 and its successor.

A new main area of our research focus will be on integration. The IDEFIX platform needs to be developed further into an integrated plan, brief, and debrief solution that links and combines tools developed within TNO, other research institutes, and the Royal Netherlands Air Force. The eventual goal is to create an integral test environment for planning, briefing and debriefing. Within this environment, a data flow will pass all the stages of the mission and will be used to supply the user with the information needed at every stage. We are investigating potential tools and solutions that can support this information flow.

As for now, next to the operational planning tools used by the RNLAF, we recognize a planning tool developed at TNO, which is called JPT (JROADS

Joint Planning Tool). The JPT is originally based on ballistic missile defence, but with the potential to grow into a more generic planning tool (Griffith, D.A., 2003).

For the final stages of the information flow we foresee the use of GRACE, a generic reconstruction and analysis tool. GRACE will provide IDEFIX with data, which has been collected, synchronized, and elaborated by a context independent analysis. IDEFIX will then continue with a context dependent analysis and generate objective-dependent information that can be presented.

This integral plan, brief, debrief solution needs to be incorporated and evaluated in large-scale international exercises that, preferably, combine live, virtual and constructive simulations, enabling us to make a step forward in developing debriefing systems for the next generation.

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