

SYNTHETIC TECHNOLOGIES – A SELECTION SCHEMA FOR FUTURE AIRCREW TRAINING SYSTEMS

Steven J. Tourville, PhD
Lockheed Martin Simulation,
Training & Support
Orlando, FL
Steven.J.Tourville@lmco.com

Richard T. M. Deverson, LCDR Royal Navy
UK MFTS,
Defence Procurement Agency
Abbey Wood, United Kingdom
UKMFTS-ERM1@dpa.mod.uk

ABSTRACT

The UK Ministry of Defence (MoD) have recognised a gap exists between their *current* training capabilities designed to support a past generation of *ab-initio* flying training requirements, and the *projected* need to produce aircrew capable of performing in next-generation operational aircraft with modern mission systems. The MoD is responding by conceptualising a future UK Military Flying Training System (UKMFTS) system design, to which industry is anticipated to propose a number of future synthetic technology solutions. Any evaluation of new, potentially emergent, synthetic capabilities to support claims of integrated training capability, however, must include informed consideration of how such technologies are conceived in *current* practice, the degree of effectiveness, and for what *projected* purposes these may be used in relation to future training systems.

Thus, the MoD sponsored an applied study into in-service synthetic technologies and protocols, viewed in terms of how these may become integrated into a next-generation flying training system. The study includes assessments of sixteen cross-functional synthetic technology areas, *current* and *projected* applications, a Technology Readiness Level (TRL) construct, and a summary-level schema intended to inform MoD decision-makers on selection protocols where synthetic technologies are conceptualised for training system purposes.

This paper describes the study approach and synthesises the synthetic technologies assessment and schema results. Data to be reported within each synthetic technology area include: (1) current and projected advantages and limitations (*e.g., speech recognition systems provide a practical mechanism to navigate MFD screens, however, high-noise and/or stress environments cause imperfect results*); (2) TRL; (3) projections of future training techniques (*e.g., advanced distributed learning systems enable change in training delivery strategies to an 'online' flight school paradigm*); and (4) projections of training tasks, methods, or related purposes, as may be applied to an future flying training system's operational capability.

ABOUT THE AUTHORS

Steven J. Tourville is a program manager and senior training systems analyst with Lockheed Martin Simulation, Training and Support. He is experienced as a US Air Force Joint Special Operations Command mission planner, an MC/EC-130E/H navigator instructor/evaluator, an HC/MC-130P/N simulator instructor, and an applied training systems research analyst. He is currently responsible for requirements analysis and system design for the UK Military Flying Training System (UKMFTS). He holds a Doctorate in Adult Education, Training and Learning Technologies, and multiple post-doctoral certifications in Program and Quality Systems Management.

Richard T.M. Deverson is a Royal Navy Lieutenant Commander and Requirements Manager on the United Kingdom Military Flying Training System Integrated Project Team (UKMFTS IPT). His direct responsibility is the future provision of appropriate synthetic training for all UK Ministry of Defence Aircrew, which includes the duty to manage the delivery of the UKMFTS Live/Synthetic Study. As a Fleet Air Arm Helicopter Pilot, he has flown Anti-Submarine, Airborne Early Warning and Search and Rescue variants of the Sea King Helicopter, followed by flying duty in the RN Maritime Lynx. He is a Central Flying School A2 Qualified Helicopter Pilot Instructor.

SYNTHETIC TECHNOLOGIES – A SELECTION SCHEMA FOR FUTURE AIRCREW TRAINING SYSTEMS

Steven J. Tourville, PhD
Lockheed Martin Simulation,
Training & Support
Orlando, FL
Steven.J.Tourville@lmco.com

Richard T. M. Deverson, LCDR Royal Navy
UK MFTS,
Defence Procurement Agency
Abbey Wood, United Kingdom
UKMFTS-ERM1@dpa.mod.uk

INTRODUCTION

The UK Ministry of Defence (MoD) recognise a gap exists between current training capabilities designed to support a past generation of *ab-initio* flying training requirements, and the projected need to produce aircrew capable of performing in next-generation operational aircraft with modern mission systems. The MoD are responding by conceptualising a future UK Military Flying Training System (UKMFTS) system design, to which industry is anticipated to propose a number of future synthetic technology solutions.

Evaluations of new, potentially emergent, synthetic capabilities to support claims of integrated training capability, however, must include informed consideration of how such technologies are currently used, the perceived degree of effectiveness, and for what purposes these may be projected in the future training system. Thus, the MoD sponsored an applied study into synthetic technologies, the aim being to develop a protocol that can inform decision-makers on training and learning capabilities, and the range of possible employment opportunities in a next-generation *ab-initio* flying training system.

In response, the study included expert assessments of several synthetic technology areas; a current and projected applications schema, and a [NASA] Technology Readiness Level (TRL) assignment, all intended to provide a high-level selection protocol where synthetic technologies may be conceptualised for future training system purposes. This paper provides a description of the overall study approach, followed by a synthesis of the synthetic technologies assessment results. Data reported include the potential advantages and limitations to utilising such technologies, and the synthetic technology selection schema, which includes: (1) current and projected employment opportunities; (2) TRL assignments and risk categorisations; (3) expert projections of future utilisation techniques; and (4) SME projections of training tasks, methods, or related purposes, as may be applied to a future flying training system's operational capability.

APPROACH

At the outset, the candidate technology areas for investigation included a broad range of both current and emerging technologies – from civil and military, and flying and non-flying applications. While some candidate technology areas were considered applicable at the training unit level, a more relevant study goal was an assessment of technology capabilities at higher-level training system support levels in a possible future conceptual system design. Thus, the focus was on identifying areas where it may be assumed that technology can influence the future make-up of a future *ab-initio* flying training system.

A secondary assumption was that traditional synthetic technology (e.g., traditional simulation, Computer-Based Training (CBT), Computer Aided Instruction (CAI), etc.), will continue to offer well-known training capabilities, and these will continue to evolve in both technological and capability terms, and will continue to offer ever-increasing opportunities to expand the horizon of employment options in the future. However, it was acknowledged that an investigation of these same traditional synthetic technologies across well-established domains would not provide the required focus on how existing or future technologies may provide additional 'could be' opportunities to evolve the system's overall training strategies or, at the least, offer a significant progression in terms of 'next generation' training methodologies and strategies.

Thus, as the range of technology areas to research had the potential to become quite large, the study team's first task was to limit the research along pre-defined lines by developing a list of potential synthetic technology focus areas that could be agreed for subsequent coverage. The intent was to seek input from the MoD as to those specific areas in which there may be stakeholder interest, and to gain agreement on a defined list of technology research topics.

This initial task required a wide-ranging research effort to collect public domain and relevant non-proprietary, non-restricted technical data from library, journal,

Internet, and other research sources, as applied across a number of current training and learning domains in the public and private sectors of business, education, military, and applied research laboratories.

Additionally, a concurrent analysis was performed on the full set of MoD training requirements data. This analysis involved various levels of data reduction of all Training Needs Analysis (TNA) data, to include syllabi, datapack training objectives, and criterion standards. The intent was to fully understand the training need for all (19) required aircrew positions, and to establish a proper basis of possible opportunities for synthetic training strategies to be employed.

The study team also accepted, based upon domain experience in development of training technology systems, training system design, administration, and management; and attendance at technology conferences, that advances in technology tend to be constant and oftentimes overwhelming. Thus, no single person or agency appears to have all answers as to where technology may be headed, or to how these may be relevant to an applied *ab-initio* training and learning environment.

As such, it was acknowledged that vendors tend to claim a range of training problems can be solved, but subsequent analyses rarely demonstrate a single solution as a panacea. Additionally, proponents of some technology areas may also offer possibilities that are desirable, but may also be impractical.

Thus, the next step was to focus questions at informed institutions, agencies, and commercial vendors. In this regard, colleagues, industry partners, and other mission area and programs (e.g., F-35, F/A-22, C-130J, Merlin, etc.), were surveyed on how instructional technologies are expected to mature, and how these may be applied in innovative ways to enhance training and learning processes. These interviews resulted in several promising technology subjects that appeared to offer potential to support the future *ab-initio* aircrew training need, as corroborated by the study team's analysis of all UKMFTS TNA and associated data.

Next, recognized future technologists were identified and surveyed along similar lines of inquiry. These expert individuals represented the Lockheed Martin Simulation, Training & Support (LMSTS) Internal Research and Development (IRAD) organization, the LM Cooperative Research and Development (CRAD) organization, and the LM Advanced Technologies Laboratory (ATL). Information was solicited from these individuals and groups based upon their unique perspectives gained from promoting internal technology

awareness, technology transfer, and technology integration across relevant programs. In this case, individual technologist teams were requested to respond to the specific study charter by validating the original list of possible technology areas, and by providing useable data that could corroborate the potential for successful employment in *any* applied training domains (i.e., civil, military, flying, non-flying, etc.).

Finally, acknowledged Subject Matter Experts (SME) within several commercial organizations, Universities, service laboratories, and military organisations were surveyed as to how current training programs may be improved using techniques presupposed by the identified technology interventions. These experts were also requested to assess the state of current and/or emerging training, learning, and simulation technologies (i.e., assign current and future TRL ratings), and to identify what these may offer in terms of advantages and limitations to all training and learning professionals.

The collective survey/interview efforts resulted in an MoD-agreed listing of sixteen technology focus areas, extensive SME data regarding current employment practices across multiple domains, expert TRL and risk ratings, and specialist projections of possible training and learning employment strategies. The following sections summarise the study results, and concludes with a final presentation schema (Attachment 1), that was developed to provide the MoD with a top-level depiction of a range of technology application considerations that may impact the future construct of the UKMFTS *ab-initio* flying training system.

RESULTS

Intelligent Agent (IA) Systems

Intelligent Agent (IA) systems provide users with modular, reusable, and scalable solutions for informed decision-making within software-based systems. IA systems may be used in similar ways as 'shop-bots'; as in web-based retail applications, to provide context-specific recommendations for unusual training circumstances, or to provide advisement for advanced or deficient students based upon previous assessments and/or training histories.

While not normally viewed as a training 'media,' IA systems may be assigned various roles across a range of system administration and management requirements and, as such, this technology area can provide opportunities to increase training system performance.

For example, IA systems may be utilised to monitor training data. Examples may include maintaining lookouts for training delays, resource levelling problems, student course and/or unit completions, instructor continuity violations, etc. Additionally, IA may translate data, for example, by identifying adverse trends in logistics flows, providing automated notifications of medical or other qualification status, providing updated training flows based on current environmental factors, etc. IA may also be used for data collection purposes, for example, to monitor student usage of on-line training materials, to assess time-to-completion in certain training units, and to track assessment results. These data may then be purposed to suggest recommended study topics for both exceptional and/or marginal students.

IA systems may be used to mitigate local unit bandwidth limitations by performing large-scale data reductions at the data input source, and transmitting only analysis results intended for decision-makers. For example, IA systems may be hosted at the local flying training unit for specific training management purposes, and only 'customised' data sets may be sent for automatic reporting purposes to headquarters, to minimise overall administrative requirements.

Limitations. IA systems utilise open architecture concepts, which implies further technology development may not be as efficient to those contained in system-specific, optimised software applications. Users should consider if IA systems may compromise current information technology architecture systems, or if this affects the current computing structure across a local Wide/Local Area Networks (WAN/LAN). Additionally, IA systems are in an early maturity state in addressing information security issues. Users should consider what data are to be held private, and if any uses of IA systems pose a potential breach of data security protocols, or could compromise an individual's right to data privacy.

As in the previous point, IA systems offer a potential for unlimited access to data, which could overwrite data classification levels, which may be required in strict access-control situations. Additionally, users should carefully consider if IA systems may be used in cases where classified data are resident or where sensitive tactical information has the potential to be compromised.

Adaptive Learning (AL) Systems

Adaptive Learning (AL) systems may be used to target specific training requirements – to remedy individual student performance deficiencies. For example, AL

systems may be embedded within CBT modules to monitor student performance whilst undergoing training and, where deficiencies are noted based on embedded assessments, alterations in module content may be suggested or automatically provided. AL systems may also be used to learn/adapt from the lessons of the training experience itself, and to later provide even wider ranges of interventions based upon earlier learning achieved from the dynamic situations (i.e., intelligent analysis of student solutions using example-based problem-solving).

Additionally, students that perform successfully in synthetic missions do not always provide identical performances in achieving the same level of success, and AL systems may be used to learn the performance range that leads to successful achievement. Thus, such systems can record the positive and/or negative experiences, and assist in developing the parameters for further training curricula content and strategies.

AL systems also permit both long-range and short-term adaptive scheduling, resource allocation/re-allocation, and student throughput assignments based on system 'fitness.' For example, AL systems may apply fuzzy logic or 'if-then' precepts to solve on-going or unexpected training administration problems (*e.g., ...if a live aircraft training sortie is forced to recover away from home field, what is the next possible training event that may be accomplished without breaking contiguous flow parameters?*). Finally, AL systems may be used to predict the effectiveness of training system components. For example, AL may be employed to learn the Mean-Time-Between-Failure (MTBF) of a training system resource, and then use these data to predict failures that can affect smooth training flows – before they happen.

Limitations. AL systems require considerable effort to prepare existing data (i.e., similar to data mining, where a complex data 'cleansing' process is first used to transform relational databases into formats that can be converted into useable knowledge). This limitation poses significant challenges that can make most implementations difficult, oftentimes requiring high-level expertise in Artificial Intelligence (AI) technology, to assure proper integration across hosted platforms. Again, this can make an implementation both difficult and expensive. Finally, the ability to migrate AL protocols to defined user populations is highly computing-device dependent, which may avert alternative training delivery strategies such as mobile and/or PC-based computing systems, wireless networking systems, etc.

Virtual Reality (VR) / Head-Mounted Display (HMD) Systems

Virtual Reality (VR)/Head-Mounted Display (HMD) systems provide users with freedom-of-movement whilst undergoing training. This technology is relatively inexpensive and easy to use, and data suggest this methodology tends to be effective in reducing overall time-to-train. VR/HMD systems may also be effective in assisting trainees when visual conditions are degraded (e.g., while performing live or simulated flight operations at night or in adverse weather).

VR/HMD systems may be used to aid viewing of fundamental flight data that can augment situational awareness in both trainees and instructors (e.g., such systems may be used in student pilot training to project visual flight path/glideslope vectors that can enhance the acquisition of an approach and landing 'picture'). It is also possible to provide 'virtual tours' of flight scenarios as trainees learn to interpret in-flight information, for example, appropriate flight altitude/speed parameters, visual checkpoints, or proper formation rejoin and/or intercept 'pictures.' Finally, as another example, users of VR/HMD systems may also be presented with images or data regarding adversaries in-flight, target locations, weapons status, etc.

Limitations. VR/HMD systems, in their current state, tend to require specialist maintainers and tools to provide on-going repairs and calibration. For example, a VR/HMD system that has not been properly adjusted to an individual's own eye-point will likely result in the user becoming distracted, possibly even ill, during training, as a result of their own attempts to view and interpret data that are not presented clearly. This has the potential to cause a significant safety issue if used in-flight. Additionally, VR/HMD systems have limited field-of-view capability that does not typically cover the full sensitivity/range of the eye, thus necessitating rather elaborate fitting procedures. Such systems also have difficulty dealing with the translucent characteristics of most helmet visors, which may distort the spherical area of the HMD and limit usefulness, possibly even compromising safety. These systems also tend to be affected by bright environmental lighting conditions. Additionally, and perhaps most problematic, VR/HMD systems require labour-intensive and custom fitting procedures per user, per use, and this will likely require additional staffing of specialist personnel. Finally, VR/HMD systems are subject to varying levels of latency and bandwidth issues depending upon the data presentation requirements, and this circumstance presents a potential to promote conditions similar to that seen in simulator sickness and/or spatial disorientation episodes.

Augmented Reality (AR) Systems

Augmented Reality (AR) systems represent a promising technology area that may be used to mitigate the cumbersome and oftentimes error-prone nature of either online or offline, i.e., paper-based presentations of coursework or reference materials to trainees. For example, students may be provided opportunities to practise learning objectives and, whilst using some form of head-mounted or see-through AR display, can reference in real-time the specific procedures required for the training objective in question. AR systems may also be used as a performance support tool – to supplement reality in a manner that traditional simulation technology is not yet capable of providing for *ab-initio* training purposes. For example, students may be provided with opportunities to perform actual flight operations, while at the same time being provided with augmented synthetic training cues (e.g., airborne or ground targets, reference points, synthetic instructors/coaches, etc.). This same example may be proposed in a reverse scenario, where simulated flight is augmented with live data from actual flight sorties.

Thus, AR systems can provide opportunities to enhance current training protocols in live platforms where the physical environment is already fully accurate. For example, students may be presented with a simulated aircraft cockpit (e.g., a simulated HUD system where one does not actually exist, or simulated weather conditions that differ from the actual weather conditions, etc.). It should be noted that AR systems also offer limited risk of negative transfer between the live and synthetic environments, and thus the potential exists for positive training transfer.

Limitations. AR systems using HMD equipment present bulkiness (i.e., a possible safety of flight issue with ejection considerations) and system expense challenges that cannot be overlooked when considered for *ab-initio* flying training purposes. AR systems continue to have accuracy of system registration and tracking as problematic challenges, especially over longer distances.

Additionally, there exists some potential for negative training circumstances when live environments do not fully react to the AR stimuli. For example, when AR systems are used to simulate missile launches, which do not result in 'real' target physical damage, novice students may experience mental disconnects, however, this is a less likely phenomena in experienced students or line aircrew. Finally, limited eye-point real estate in AR/HMD systems requires a human factors consideration/research into how data should be properly represented for effective training purposes.

Data Mining (DM) Systems

Data Mining (DM) systems are used to convert existing data into knowledge repositories that, in essence, maximises previously untapped system assets. Abundant data collection opportunities exist within flying training organisations, and data sources and knowledge to be extracted from these are only limited by imagination. For example, turning discrete time-to-completion data into aggregate knowledge may uncover problematic training bottlenecks.

Additionally, optimal patterns of air experience behaviour (i.e., what constitutes proper airmanship skill) may be defined from the data recorded by all past successes. In this sense, DM systems can provide significant help in uncovering hidden patterns in data. For example, patterns such as repeated test item failures, in isolation, may not point to a specific problem. Over time; however, such data may identify that a particular test question is a repeating problem, which may then point to problems with test item validity, lesson content, or an instructional methodology/strategy.

DM systems provide an 'intuitive' capability to determine abnormal operational patterns, where trends exist, and/or if process improvement opportunities may be made by comparing year-over-year historical trends and [evolving] extant data sets. For example, it may become evident, using DM techniques, that classes reaching a particular phase of training at a particular time of year (e.g., with characteristic adverse weather phenomena and effects) tend to have high wastage rates. While this may be an intuitive example, in this and in many other examples, DM systems can be designed to deliver the right data to the right people at the right time, thus maximising the efficiency of overall data reporting and potential recommended courses of action.

Limitations. DM systems utilise predictive modelling techniques and, thus, cannot be expected to predict the future with 100% accuracy. Given the basis of predictive analysis, the issue is one of statistical significance. Over smaller population data sets, or over shorter periods, the issue of significance is problematic, and results must be tempered as such. Over larger datasets, the significance issue becomes smaller, making DM techniques more attractive.

Finally, DM systems require a pre-established data collection strategy at the point of data entry, and a significant data 'cleansing' strategy is required to determine proper relationships once data are collected – all of which may be long and involved undertakings. Finally, DM systems are a relatively new technology with only limited tools available. In this same vein, DM

systems technologies are highly-dependent upon expert users whom are able to direct focused queries to meet the intended results, and this presents both staffing challenges, and risks that specialist bias may be introduced into any subsequent analyses.

Decision Support (DS) Systems

Similar to DM systems, Decision Support (DS) systems may be used to optimise business practices in general, and training management functions specifically. For example, DS systems may be used to incorporate new knowledge into existing training curricula, or this technology may be used to provide periodic or automated updates to SCORM-compliant courseware.

Like IA and DM systems, intelligent DS systems may be used to determine abnormal operational patterns, trends, and/or process improvement opportunities by comparing historical trends and evolving extant data sets. For example, this technology may be used to query a suspected high number of student attritions over time at a particular academic, synthetic, or flying training node and the results may be indicative of a training delivery, simulator scripting, or perhaps a scheduling (e.g., aircraft) problem.

As another example, DS systems may be used to provide if-then relationships on certain pre-defined training variables (e.g., *...if a criterion standard on a particular training requirement is increased to __, then, based on current failure rates, a new failure rate may be expected to [increase/decrease] to __% of the student population over time*). DS systems may also be used to provide concurrent modifications to course sequencing and/or structures, and perhaps even for updating resident syllabi. Thus, DS systems may be used to deliver the right data to the right people at the right time, thus maximising the efficiency of any data collection effort that requires information to be turned into data reporting for possible future action.

Limitations. DS systems utilise predictive modelling and artificial intelligence techniques that cannot be expected to fully predict the future with full accuracy. Such systems require established data collection strategies at the data entry point, and require involved data 'cleansing' efforts to determine proper inter-relationships, which can be a difficult undertaking. Additionally, DS systems are dependent upon neural net technology to read codified examples and determine decision options. Finally, such systems also require expert users whom are able to direct focused queries that meet the intended results, and this may introduce some degree of bias into any subsequent analyses.

Knowledge/Learning Management (KM/LM) Systems

Knowledge Management (KM) / Learning [content] Management (LM) systems may be used to enable training programs to become distributed, managed, and assessed across practices, specializations, and geographies, in an efficient, quick, and relatively low-cost manner. For example, such systems can enable centralised student record-keeping and tracking of training progress. Such systems can also be used to track resource utilisation and effectiveness metrics to justify future capital expenditures. For example, KM/LM systems can provide information on the training effectiveness and/or utilisation efficiency of a particular resource, and this information may then be used to provide further justification for increased usage, or further investment in additional and/or upgraded resources.

KM/LM systems can enable long-term, short-term, and on-the-fly training management planning functions in terms of resource re-purposing and/or re-allocation. For example, instructor currency or training facility availability may be tracked in real-time and, in the event of an unexpected resource failure, such systems can update the resource allocation and/or schedule as needed to accommodate the day's training need.

KM/LM systems may be used to enforce consistent standards by employing configuration-management protocols across resident training materials, and to efficiently deploy updates (especially on modules developed as SCORM-compliant learning objects). For example, KM/LM systems can track currency dates of all courseware in all systems, and this ensures each booked trainee receives only current training materials for the specific curriculum requirement.

Limitations. Employment of KM/LM systems requires a well-established understanding of the ontology and taxonomies of the training enterprise or, if deployed across multiple organisations with varying training purposes and/or other unique differences, multiple ontologies and taxonomies must be dealt with. Additionally, the ability of such systems' to detect non-routine and/or unstructured change continues to require subject matter experts versed in recognising training system abnormalities. Finally, standards for data content interoperability (i.e., in accordance with ADL and/or SCORM standards) are currently in an evolving state, and these are likely to result in significant investment over time to re-purpose current management data required by the knowledge and learning management system.

Speech Recognition (SR) Systems

Speech Recognition (SR) systems permit individuals to become freed from using their hands to communicate with a computing system, allowing users improved focus on the task being performed. SR systems provide a potential to increase productivity, especially in traditional data interpretation roles. For example, SR systems can provide a useful mechanism for aircrew to navigate Multi-Function Display (MFD) screens – by simply speaking which data are required.

SR systems can increase the functionality of HMD systems, if integrated for data management purposes, on devices with limited data presentation real estate. For example, HMD systems could be set to display only flight-critical information to pilots and, upon speaking a request for further intelligence information, the previous display could be replaced with the required tactical flight information. Such systems have relatively low implementation costs, and multiple COTS products assure a relatively long-term supported technology base.

Limitations. High-noise environments tend to cause imperfect results for SR system users. Additionally, high-stress (i.e., physical and emotional) environments often result in changing tonations, that tend to result in significantly reduced recognition accuracy. For example, pilots operating in high-G manoeuvring environments may not be able to speak in the same manner as that of normal 1-G flight, and this will tend to affect the accuracy of any spoken request into a SR system. Additionally, such systems' software base is currently only able to recognise multiple speakers on a very limited basis, and this capability is exponentially reduced in higher-noise environments. Finally, current research in SR systems is devoted to better software algorithms, and research in proper human factors design of speech-user interfaces appears to be lacking.

Information Technology (IT) Architecture Systems

Information technology architecture systems, as a broadly defined area of Information Technology (IT), may be used to ensure interoperability across a 'system' or organisation by providing common sets of information/data exchange standards that can then be used to reduce the complexity of data-sharing across functional units. For example, where units are geographically dispersed, an IT architecture system can help ensure all reporting between affiliated units, and headquarters, share a common basis in design and content, as applied against set standards for technology-enabled information sharing.

IT architecture systems may be used to inform stakeholders of large-scale business plans, directions, and objectives. Again, a common information-sharing standard brings efficiencies that are simply not present when individuals are hosted with dissimilar computing platforms.

IT architecture systems may also be used to provide a proper framework for future computing platform/software investments. For example, periodic computing systems/software migrations are a fact in most any enterprise that hosts multiple computing systems. Where such systems are based on common architectures, these can be more easily updated, perhaps even remotely from the system administrator's desktop when remote update protocols have been established. Finally, IT architecture systems can help to provide alignment between the technology providers and the business functions. Common IT architectures enable administrators and managers to align organisational computing needs with technology requirements. Thus, such systems also potentially reduce ongoing maintenance and support requirements by integrating a common infrastructure across the organisation, or by supporting new technology migrations.

Limitations. IT architecture systems may be a very involved endeavour to start, especially in cases where the current infrastructure is not well established, or when these are composed of multiple and/or disparate legacy systems with interoperability and concurrency challenges. Such systems can also significantly disrupt unit operations when new information exchange standards differ from the current state, ultimately increasing the complexity of data sharing across functional units.

IT architecture systems may increase local unit workload (at least initially) between the technology providers and the higher-level business functions (e.g., support and maintenance requirements may be increased when done in-house). Finally, IT architecture systems may be only partially able to support new technology migrations depending upon the level of complexity in the current IT architecture system.

Advanced Distributed Learning (ADL) Systems

Advanced Distributed Learning (ADL) systems can provide the means to develop a self-directed learning environment, whereby instructor roles become changed from a transmitter of information to a facilitator of the overall learning processes (i.e., a mentoring approach). For example, where ADL systems are employed, courseware may be accessed by students anywhere, anytime, and the responsibility for learning then shifts

from the instructor to the student, who must logon and receive the training needed, possibly followed by an instructor summation period (e.g., in a traditional classroom). As presented, ADL systems may save manpower and resource (e.g., facilities, etc.) costs by providing a learning environment that shifts training strategies from traditional delivery modes to online; self-paced delivery ontologies, which also ensures consistent delivery of current training content – every time and for every student.

ADL systems may also provide a proper approach for courseware to become interoperable across different conformant KM/LM systems, and these can become widely accessible using standard, supportable, web browser products. Such distributed learning applications may also provide a strategy for training development costs to be further amortised over larger populations of learners. Finally, ADL systems can provide a methodology where learning materials are content-searchable, tailored to specific student needs, and reusable across training system elements or modules, thus maximising the investment in training development efforts for technology-enabled learning materials.

Limitations. Development of web-enabled learning materials in accordance with ADL protocols may require staffs with specialist expertise in both technology-enabled course content, and online instructional/learning methodologies. Additionally, current network configurations and server bandwidth limitations may not be capable of supporting the minimum required ADL protocols that support online learning content, including real-time video and audio – all current bandwidth technology challenges.

ADL strategies tend to suggest that all learning content should be exported to a distributed methodology, and this may create a paradox of inappropriate learning methodologies for the required training domain (e.g., employing an inappropriate online CBT strategy to support psychomotor development versus the more appropriate advancement of knowledge-based skills). Finally, ADL systems do not fully address difficult curriculum control issues such as intellectual property rights and copyright management in a sharable online learning domain.

Modelling and Simulation (M&S) Systems

Modelling and Simulation (M&S) systems can enable alternate realities to be created and 'what-if' scenarios to be tested, and these are only limited by imagination. For example, M&S technology may be used to create realistic tactical operations scenarios, with multiple and

dissimilar units, for mission rehearsal and testing purposes. M&S systems may be used to model and then simulate hazardous and/or complex system conditions requiring difficult resource allocation considerations, development of training interventions, or alternative contingency planning efforts.

For example, M&S may be used to demonstrate the 'fitness' of a particular resource strategy, by altering variable elements (e.g., student throughput, adverse weather conditions, training methodologies, resource failures, etc.) to test for pre-determined breakdown conditions.

M&S systems may be used as a data collector and subsequent assessor for determining potential conceptual system competency, or for simulating long-term effects from accelerating pre-determined events in a linear or event-based fashion. For example, such systems may be used to introduce adverse conditions into a training circumstance that otherwise may not be guaranteed to happen, or that are not safe to occur in live training circumstances (e.g., windshear, multiple air traffic flight path vectors into terrain, critical component system failures, etc.).

Additionally, M&S systems can standardise training scripts across multiple subjects. Finally, such systems are generally less expensive to own and have greater availability than actual equipment.

Limitations. M&S systems offer variations in available fidelity (i.e., level of detail/completeness) and cost (i.e., initial development/production and/or on-going maintenance investment), and the selected fidelity level investment may have a profound impact on trainee performance, possibly including an element of negative transfer. Higher-fidelity M&S system functionality is directly correlated to computational power, and tradeoffs are required between training need versus the ability to accurately simulate the task [requirement].

M&S proponents tend to suggest synthetic training devices must fully replicate the entire performance domain; however, proper M&S only require training needs analysis data to support both cost justification decisions and the proper implementation/integration path into the affected training system.

Game Technology (GT) Systems

Game Technology (GT) systems may be used to leverage the 'enjoyment' factor inherent in successfully applied learning strategies, to maximise training effects and to create positive training environments where trainees may seek out additional learning opportunities (perhaps even during free time). GT systems have

advanced where these may not only be used for part-task training purposes, but may also be very reasonably used for some higher-level training requirements, potentially including team-based interactions using Internet-based online learning strategies.

COTS gaming products offer very real cost-efficiencies over specialist/highly engineered products, and market penetration factors with game technology systems have enabled rapid beta testing environments, in more robust forms than that provided in traditional one-off products. Finally, current GT, coupled with recent and significant advancements in PC systems, now offer a level of fidelity typically found only in past-generation high fidelity computing and image generation products. GT systems now offer more than adequate fidelity for most training needs, and higher-fidelity, higher-cost image generation and computational power is no longer required for a good portion, if not all, of the part-task, lower-level training task requirements.

Limitations. Some lower-fidelity GT systems may not be appropriate for some higher-level training tasks, and training needs assessment trade-offs must be fully addressed when considering COTS gaming technologies versus customised simulation solutions. Risk of negative training effects with GT systems must be considered, especially in terms of tactile response inherent to COTS controllers, and in over-simplified vehicle dynamics, opponent force behaviours, or environmental modelling capabilities.

Additionally, the lack of empirical data to determine proper tasks that may be trained using GT systems, and the unknown live/synthetic balance equation must be considered. Additionally, the typical time compression strategies used in many GT applications may be inappropriate for some elements of training, especially where realistic training is required. Finally, lack of SCORM, HLA, or Learning Management systems standards compliance in GT systems may be contrary to other hosted technology initiatives (e.g., ADL protocols, IT architecture systems, etc.).

Micro-Simulation (MS) Systems

Micro-Simulation (MS) systems offer similar advantages to that of high-end simulation, GT systems, and PC Technology systems. That is, such systems may be used to practise some level of training tasks repeatedly, using equipment that can be acquired with significantly less investment. Such systems are also less expensive to operate than live equipment, perhaps more affordable than the next level of full mission simulation, and possibly even more cost-effective than lower-level cockpit procedures trainers or part-task training devices.

Additionally, these systems tend to be relatively easy to install, inexpensive to maintain, and replacement/update decisions oftentimes involve simple throwaway choices. MS systems can be configured in many ways, to integrate with existing CBT, to provide standardized training content to users, to provide part-task training tasks, or to provide some level of full-mission over-training intended to strengthen a trainee's automatic response function.

In addition, MS simulation systems may be used to assess trainee performance in real-time during training scenarios. The bottom line with such systems is that a significant portion of both full-mission, simulation-based, training and perhaps even some portions of live training can be downloaded using a MS strategy. The real question with this technology is "...to what degree does the fidelity of the simulation need to match the training need?" (i.e., suggesting a need for a well-founded training needs analysis).

Limitations. MS systems cannot always compete with higher-end simulators in terms of synthetic natural environment fidelity and, in some cases; both the physical and/or synthetic natural environment chosen for MS purposes may be inadequate for the training task requirement (i.e., the comparison may not be one-to-one as the true training purposes may be quite different). Additionally, MS and COTS controller technology presents an increased risk/challenge of inducing some degree of negative training effect in terms of tactile and/or psychomotor responses, and proprietary licensing issues may negate a user need to modify the hardware for specific purposes.

Additionally, users may require specific training in the operational characteristics and control of MS systems, which could potentially waste valuable training time or create negative learning effects. Single-monitor micro-simulation systems may also create poor visual habit patterns (e.g., inability to employ peripheral vision, poor instrument-to-visual scans, etc.).

The lack of a motion feedback system in MS may result in disorientation that could possibly exacerbate itself in the live training environment. Finally, MS systems are, for the most part, moveable; but these systems do lack true portability – which can limit the overall perceived system usefulness.

Personal Computing (PC) Systems

Personal Computing (PC) systems offer the capability to improve user-level interaction during training, possibly increasing learning ability and the rate of performance improvement, and to enhance the overall training

experience for students, instructors, and staffs. PC systems (e.g., laptop computers, PDAs, etc.) using high-resolution displays may also offer the potential to take higher-order training concepts into the classrooms, or to export curricula (and class notes) to at-home desktops, thus potentially turning free time into productive training time, with adequate fidelity to support and potentially download many higher-level training tasks.

PC systems also offer portable solutions for administering or receiving automated training and testing materials anywhere, anytime. Such systems may enable instructor-to-student ratios to be altered as training administration (e.g., automated student monitoring) ability becomes much improved. PC systems can also provide the means to rapidly disseminate course material updates and/or provide real-time information in the event of unplanned events (e.g., schedule changes, etc.).

Limitations. Prices for PC systems tend to run higher than that in equivalent desktop alternatives. PC systems' weight may not truly represent a portable solution, especially if multiple peripherals are required. Limited battery life, limited connection ports, and limited CPU speed/memory capacity are problematic issues with PC systems.

Additionally, system upgrades can be quite costly and, in some cases, not possible due to the inherent design limitations of portable devices. For PC systems to be effective in providing anytime, anywhere data access, web-access is required, suggesting a need for a modem and Internet connection, or a wireless network system.

PC system displays are smaller than desktops, suggesting a limited usefulness for those training tasks that require high eye-point real-estate requirements (e.g., a need to view full instrument panels, etc.). Finally, PC systems offer limited sunlight-readable displays, and some are difficult to use (e.g., graffiti-style data input on PDAs).

Mobile Computing and Wireless Networking (MC/WN) Systems

Mobile Computing (MC) and Wireless Networking (WN) systems may be used to provide timely access to real-time data for improved decision-making. MC/WN systems can permit faster and more accurate decision-making; and may improve productivity by moving staffs away from their desktop environments to the actual work locations.

MC/WN systems can reduce error rates caused by double-journaling, and can offer the potential to convert slack time into productive time. Such systems offer relatively low system implementation cost and simple expansion as requirements grow. Such systems also provide a rapid deployment capability, and this eliminates the need to hard-wire physical structures. Finally, MC/WN systems provide the capability to provide rapid dissemination of training information, including operational data (e.g., changed schedules, new training materials, etc.).

Limitations. Limited data transfer rates and a higher-than-normal potential for data loss in wireless applications remain a problematic issue in MC/WN systems, especially where a single wireless node is in place for multiple mobile applications. Mobile equipment tends to suffer from limited battery life, which can significantly reduce the ability to complete work assignments in any mobile network implementation. Mobile equipment also suffer from small screen displays, and a print capability may be needed to view full documents in some cases. Additionally, depending upon the current desktop computing infrastructure, there may be software compatibility issues. Mobile workers will inevitably move out-of-range of the wireless access points, and insufficient signal strength or other interference (e.g., microwave transmissions) can prevent or reduce stable communications. Self-configuring protocols are also needed in mobile equipment in those cases where large-scale wireless networks exist with, perhaps, thousands of micro-cell nodes. Finally, and rather importantly, wireless networks remain a data security risk.

Embedded Training Systems

Embedded Training (ET) systems offer a means to utilise operational equipment in the operational environment. For example, advanced pilot training may be enabled by providing a means to practise tactical skills when live ranges or adversaries are unavailable. Additionally, an ET system can optimise a host platform's efficiency by enabling conjoint rear-crew training approaches, where specialist skills may be trained in the live flight environment, without disrupting other training requirements being performed by, for example, the pilot student. Thus, depending upon the application, an ET system may permit the training of multiple students in a single live mission sortie.

ET systems may also minimise concurrency issues with any live training equipment that are not concurrent with the operational equipment. For example, students may use an ET system to practise radar navigation

procedures on aircraft that are not hosted with such equipment. An embedded synthetic radar platform may be fitted on live aircraft, which enables students to experience the live flight environment and, at the same time, experience the simulated radar presentation (with a fidelity level that appears to be as the real radar system, thus maximising training transfer and overall sortie value. ET systems offer similar benefits to simulation, but these can be presented in the live training environment, permitting earlier attainment of, for example, airmanship. Such systems may allow portions of operational conversion or front-line training to be downloaded. Finally, ET systems may offer a software re-use potential in those applications developed specifically for simulation training purposes.

Limitations. The opportunity to use ET systems to maximise training potential may be limited by reduced numbers of live equipment fitted with such systems. ET systems require increased investment over that of simulation, and a considerable development and testing cycle maybe required in cases where there is a perceived or real impact on flight safety or aircraft certification. The ability to employ ET modes in operational systems may impose risks of inadvertent emissions or impacts on flight-critical software. Finally, where operational equipment has been dual-purposed as ET equipment, training capability may be limited to the system or sensor features of the host equipment.

CONCLUSION

The overall approach and syntheses of the synthetic technologies assessment and schema results have been presented in the previous sections. Data reported within each synthetic technology area included: (1) current and projected employment opportunities and technology limitations; and (2) projections of future employment techniques. The Synthetic Technologies Selection Schema (Attachment Figure 1) that follows also provides a summary-level schema that represents the previous results sections, and also includes: (1) current and future TRL assignments and risk categorisations, i.e., as applied to the UKMFTS current and the future states of initial-service provision (2007) and full service provision (2012), and (2) projections of training tasks, methods, or related purposes, as applied to the future flying training system's operational capability.

REFERENCES

Available from the Ministry of Defence, in the Live/Synthetic Study (Deliverable 3) Synthetic Technologies main report.

Attachment 1 - TECHNOLOGY SUMMARY SCHEMA - REVIEW OF TECHNOLOGY AREAS AS COMPARED AND CONTRASTED TO PROJECTED MFTS APPLICATIONS

| TECHNOLOGY AREA | CURRENT DATA | CURRENT ADVANTAGES (Summarised) | CURRENT LIMITATIONS (Summarised) | CURRENT TRL (OVERALL) | CURRENT TRL (FLIGHT TRAINING) | PROJECTED FLYING TRAINING SYSTEM OPPORTUNITIES / TECHNIQUES | PROJECTED TRL at MFTS ISP (2007) | PROJECTED Risk at MFTS ISP (2007) | PROJECTED TRL at MFTS FSP (2012) | PROJECTED Risk at MFTS FSP (2012) |
|---|--------------|--|--|-----------------------|-------------------------------|---|----------------------------------|-----------------------------------|----------------------------------|-----------------------------------|
| | | | | | | | | | | |
| 1. INTELLIGENT AGENT SYSTEMS (Reference Section 1) | | Can provide users with modular, reusable, and scalable solutions for informed decision-making within software-based systems; Can be assigned to perform different and multiple roles (e.g., data monitor, translator, collector, etc.) across a wide range of training administration and management tasks; Can mitigate local unit bandwidth limitations by performing large-scale data reductions at the source of data input, and then only transmitting analysis results to decision-makers. | Open architecture concept suggests this technology cannot be developed in as efficient a manner as system-specific, optimised software applications; Early maturity level of such systems has yet to fully address overall information security issues; Potential unlimited ability to access data poses open privacy issues, including in those areas where data classification levels may require strict access control. | 9 | 4 | Up-to-the-minute resource scheduling processes may be automated; Student scoring and tracking agents may be integrated into all relevant training modules; Agent-based selection of appropriate training and materials may be provided as needed for advanced and/or deficient students in training (e.g., mitigation strategies for additional training interventions, tailored training); Simulator initialisation/set-up and/or aircraft configuration as needed may be provided. | 4 | MEDIUM | 6 | MEDIUM |
| 2. ADAPTIVE LEARNING SYSTEMS (Reference Section 2) | | Can be used to target training requirements in order to improve student performance; Can be used to learn from training experiences and provide wider ranges of interventions based upon dynamic situations; Permits both long-range and short-term adaptive scheduling, resource allocations, student throughput assignments based on system 'fitness'; Can be used to predict effectiveness of specific training system components. | Considerable requirement to prepare existing data (i.e., transformation of 'cleansed' data into knowledge) poses challenges that makes most implementations difficult; High-level expertise in Artificial Intelligence technology is required to assure integration across hosted platforms; Ability to migrate protocols to user population is highly computing-device dependent, which may mitigate alternative training delivery strategies (e.g., mobile computing, wireless networking, etc.) | 9 | 4 | Students may be provided with 'electronic instructors' that utilise explanation-based generalisations and case-based reasoning; Decision-makers may be provided with automated student performance scoring, tracking, and training flow adaptation to optimise demonstrated learning strengths/deficiencies (i.e., tailored training); Training systems may be modelling across critical domains (e.g., scheduling, resource allocations, etc.) | 4 | MEDIUM | 7 | LOW |
| 3. VIRTUAL REALITY HEAD-MOUNTED DISPLAY SYSTEMS (Reference Section 3) | | Provides freedom-of-movement to users and is relatively inexpensive and easy to set-up; Can be used to aid viewing when visual conditions are degraded; Can be used to aid viewing of data that augments situational awareness in both trainees and instructors; May be used to project fundamental flight information to trainees as they learn to interpret the proper flight 'picture' (e.g., flight path and glideslope vectors, target angles, etc.). | Specialists and tools needed to provide on-going maintenance and calibration; Limited FOV does not normally cover the full sensitivity of human eye; Translucent characteristics of helmet visors may distort spherical area of HMD; HMDs tend to be affected by environmental lighting conditions; Labour-intensive/custom fitting procedures required per user, per use; HMDs subject to latency and bandwidth issues that promote conditions similar to simulator sickness and/or spatial disorientation. | 9 | 9 | Provide virtual representation of training scenarios to students; provide additional visual capability when used in conjunction with part-task simulation training; provide an alternative method of synthetic environmental scene representation when visual system limitations prevent optimal viewing (e.g., monitoring lead formation position from offset angles, etc.) | 7 | LOW | 9 | LOW |
| 4. AUGMENTED REALITY SYSTEMS (Reference Section 4) | | May be used to mitigate cumbersome and error-prone nature of online/offline reference materials to trainees; Augments reality in a manner that simulation is not yet capable of providing; Provides opportunity to enhance current training in live platforms where environment is already fully accurate (e.g., an aircraft cockpit, the actual weather conditions, etc.); Little risk of negative transfer between live and synthetic environments and, thus, high potential exists for positive training transfer. | AR/HMD equipment bulkiness and system expense cannot be overlooked when being considered in flying training applications; Accuracy of system registration and tracking is problematic - especially over long distances; Potential for negative training circumstance when live environments do not react to AR stimuli (e.g., AR-simulated missile launches do not result in 'real' target physical damage); Limited eye point real estate requires consideration of data to be represented for proper training purposes. | 9 | 4 | Projection of learning content/objects onto heads-up displays in aircraft, simulators, part-task trainers (e.g., added flight path markers/factors relevant to ab-initio training requirement); impose training tutoring stimuli over live conditions (e.g., aim points, targets, etc.); enhanced synthetic realism that includes additional overlays of scripted environmental and/or opponent variables (weather, smoke, fire, bogies, etc.). | 6 | MEDIUM | 8 | LOW |
| 5. DATA MINING SYSTEMS (Reference Section 5) | | Can convert existing data into knowledge repositories that, in essence, becomes a previously untapped system asset; Can provide significant help to uncover hidden patterns in data; Can provide 'intuitive' capability to determine abnormal operational patterns and trends and/or process improvement opportunities by comparing year-over-year historical trends and [evolving] extant data sets; Can be designed to deliver the right data to the right people at the right time, thus maximising efficiency of data reporting and action. | Utilises predictive modelling techniques and, thus, cannot be expected to fully predict the future with 100% accuracy; Requires established data collection strategies, including not only data entry, but also data 'cleansing' to determine proper relationships, which can be a long and expensive undertaking; Relatively new technology with limited tools available; Technology is highly-dependent upon expert users whom are able to direct focused queries to meet intended results, and this may introduce bias into any subsequent analyses. | 9 | 4 | Improved decision-making using predictive training outcomes and/or student performance path data; improved selection and screening data analysis; better tracking of resource allocations to training units and staffs; creation of meaningful learning outcome typologies; enhanced logistic and supply chain tracking and management, etc. | 7 | LOW | 9 | LOW |
| 6. DECISION SUPPORT SYSTEMS (Reference Section 6) | | May be used, in conjunction to optimise business practices and training management functions; May be used to quickly incorporate new knowledge into training curricula; Like Data Mining Systems (Reference 6.5), may be used to determine abnormal operational patterns and trends and/or process improvement opportunities by comparing year-over-year historical trends and [evolving] extant data sets; Can be used to deliver the right data to the right people at the right time, thus maximising efficiency of data reporting and action. | Like Data Mining (Reference 6.5), predictive modelling techniques are used and, thus, cannot be expected to fully predict the future with 100% accuracy; Requires established data collection strategies, including not only data entry, but also data 'cleansing' to determine proper relationships, which can be a long and expensive undertaking; Technology is highly-dependent upon neural net technology (which uses codified examples to determine training options) and expert users whom are able to direct focused queries to meet the intended results, and this may introduce bias into any subsequent analyses. | 9 | 4 | Automated analysis of student progress; performance scoring and tracking either by standardised criterion-referenced measures of performance; 'expert' performers, or other training participants; effective training path recommendations based on established decision criteria; automatic updates to course content as required by course modifications. | 6 | MEDIUM | 8 | LOW |
| 7. KNOWLEDGE and LEARNING MANAGEMENT SYSTEMS (Reference Section 7) | | Can enable training programs to become distributed, managed, and assessed across practices/specialisations and geographies in an efficient, quick, and relatively low-cost manner; Can be used to track resource utilisation and effectiveness metrics to justify capital expenditures; Can be used to enforce consistent training standards, to configuration-manage any training materials (especially SCORM compliant learning objects) and to efficiently deploy updates; Can enable long-term, short-term, and on-the-fly training resource re-purposing and management functions. | Requires a well-established understanding of the ontology and taxonomies of an enterprise or, if deployed across multiple organisations with wide-ranging training purposes and geographic or other unique differences, multiple ontology and taxonomies; Detection of non-routine and/or unstructured change continues to require experts versed in recognising training system abnormalities; Standards for data content interoperability are currently in an evolving state, are likely to result in significant investment over time to re-purpose current training management data. | 9 | 5 | Integration of models and simulations developed for scoring training mission risk factors; Online training assessment w/anytime, anywhere mobile training delivery; learning content reuse, efficient learning material update based on real-time flight/mission experiences (w/SCORM compliant learning objects); tailored training content based on end-assignment requirements. | 7 | LOW | 9 | LOW |
| 8. SPEECH RECOGNITION SYSTEMS (Reference Section 8) | | Individuals are freed from using their hands to communicate with a [computing] system, allowing them to focus on the task at hand; Potential for increased productivity, especially in traditional data reporting roles; Can provide a useful mechanism to navigate complex MFD screens by speaking which data are required; Can increase the functionality of HMDs if integrated for data management purposes on devices with limited data presentation real estate; Relatively low implementation cost and multiple COTS products assure a relatively long-term supported technology base. | High-noise environments cause imperfect speech recognition results; High-stress (i.e., physical and emotional) environments often results in changing tonations, that also results in significantly reduced speech recognition accuracy; Speech recognition software is currently only able to recognise multiple speakers on a very limited basis, and this capability is exponentially reduced in high-noise environments; Currently, all research is devoted to better software algorithms, and research for proper human factors for the design of speech-user interfaces has been largely ignored. | 9 | 5 | Enables use of speech synthesis in simulation; Instructors can be freed to teach tasks that require the use of hands (e.g., flight manoeuvres) while setting up simulator scripts using speech protocols; Staffs can set-up or manipulate synthetic models or objects using easy-to-recall speech interfaces; Speech-enabled computer-based instruction can be used to illuminate (describe, explain, etc.) complex information to students and/or free up Instructor resources from direct instructional activities or indirect monitoring requirements. | 6 | MEDIUM | 8 | LOW |

Attachment 1, Continued - TECHNOLOGY SUMMARY SCHEMA - REVIEW OF TECHNOLOGY AREAS AS COMPARED AND CONTRASTED TO PROJECTED MFTS APPLICATIONS

| TECHNOLOGY AREA | CURRENT DATA | CURRENT ADVANTAGES (Summarised) | CURRENT LIMITATIONS (Summarised) | CURRENT TRL (OVERALL) | CURRENT TRL (FLIGHT TRAINING) | PROJECTED DATA | PROJECTED FLYING TRAINING SYSTEM OPPORTUNITIES / TECHNIQUES | PROJECTED | PROJECTED | PROJECTED | PROJECTED |
|---|--------------|---|---|-----------------------|-------------------------------|----------------|---|------------------------|-------------------------|------------------------|-------------------------|
| | | | | | | | | TRL at MFTS ISP (2007) | Risk at MFTS ISP (2007) | TRL at MFTS FSP (2012) | Risk at MFTS FSP (2012) |
| 9. INFORMATION TECHNOLOGY ARCHITECTURE SYSTEMS (Reference Section 9) | | Can help to ensure interoperability by providing a common set of information exchange standards across the organisation, ultimately reducing complexity of data-sharing across functional units; Can be used to inform stakeholders of large-scale business plans, directions, and objectives; Can provide framework for future computing platform/software investments; Can provide an alignment between the information technology providers and the business functions; Can reduce maintenance and support requirements; Can support new technology migrations. | Can be very expensive to start, especially where a current system is composed of multiple and disparate legacy systems with interoperability challenges; Can disrupt unit operations when new information exchange standards differ from the current state, ultimately increasing the complexity of data-sharing across functional units; Increases local workload (initially) between information technology providers and the business functions; Can increase maintenance and support requirements if done in-house. | 9 | 4 | | Enables shift in training strategy from traditional centralised instruction to non-traditional, decentralised modes; Ready access to current data provides staffs with means to make efficient & rapid changes to program planning & component execution elements; Instructors can make near-real time changes to schedules based upon student assessment results; Enables better decision-making regarding proper media to be used for particular training needs; Provides better configuration control and management of electronic training materials. | 5 | MEDIUM | 7 | LOW |
| 10. ADVANCED DISTRIBUTED LEARNING SYSTEMS (Reference Section 10) | | Can be used to provide a self-directed learning environment, where instructor roles may change from transmitter of information to facilitator of learning processes (i.e., mentoring); Online training can save manpower, and resource costs; Courseware can become interoperable across different conformant learning management systems, and accessible using standard, supportable, web browser products; Training development costs can be amortised over larger learning populations; Learning materials can be content-searchable, tailorable to student needs, and reusable. | Development of web-enabled learning materials require [expensive] staffs with expertise in course content & online learning methodologies; Current network configurations & server bandwidth limitations may not be capable of supporting minimum required protocols to support online learning content, including real-time video & audio; Temptation to export all learning content to a distributed methodology may create a paradox of inappropriate domain for the required training need (e.g., knowledge versus psychomotor skills); Difficult to control intellectual property and copyright in sharable online learning objects. | 9 | 4 | | Enables an 'online' flight school paradigm where traditional academic ground-school may become distributed to [larger] audiences; Provide students with convenient and 'after-hours' access to self-paced training materials; Provide students with additional opportunities to apply training using distributed interactive and web-based part-task flight simulation methods (e.g., for basic individual and team skills practice); Post all [appropriate] training materials on-line, enabling efficient a training materials configuration management protocol, and effective electronic classroom, computer-assisted instructional strategies. | 6 | MEDIUM | 8 | LOW |
| 11. MODELLING AND SIMULATION SYSTEMS (Reference Section 11) | | Enables alternate realities to be created and 'what-if' scenarios to be tested; Can model and simulate conditions requiring allocation of resources, development of training interventions; or contingency planning; Can be used to assess competency, or to simulate long-term effects by accelerating events in either a linear or event-based fashion; Can be used to introduce conditions in training not guaranteed to happen or not safe to happen in live training events; Can standardise training scripts across multiple subjects; Generally less expensive to own and greater availability than actual equipment. | Variations in fidelity and cost; Fidelity level may impact trainee performance, possibly including an element of negative transfer; High-fidelity simulation functionality is correlated to computational power - tradeoffs are required between training speed and ability to simulate the task [requirement]; Traditional M&S proponents suggest synthetic training devices need to fully replicate required performance domain, however, proper M&S requires extensive training needs analysis data to support both cost justification decisions, and the proper implementation and integration into training systems. | 9 | 9 | | Enables virtual prototyping of conceptual system designs in a manner where training input, flow, process, and output variables can be tested and validated using predictive techniques; Enables basic through advanced skills training in a safe, non-threatening environment; Provides capability to employ repeated practise for fragile skills and reinforced feedback strategies across all appropriate training applications; Networked simulation provides ideal opportunities for team skills practise and/or tactics development; Ability to alter synthetic training parameters provides advantages not possible in live training. | 7 | LOW | 9 | LOW |
| 12. GAME TECHNOLOGY SYSTEMS (Reference Section 12) | | Can leverage 'enjoyment' factor in learning to maximise training effects, & create learning environments where trainees seek training during free time; Can be used for higher-level training requirements, including team interactions, using Internet-based tools; Market penetration factors enables rapid beta testing environment in more robust forms than that of one-off products; COTS products offer cost-efficiencies over specialist products; Current PC technology offers adequate fidelity for most training needs, high-fidelity image generation/ computational power is no longer needed for some lower-level training tasks. | Lower-fidelity systems may not be appropriate for all training tasks & trade-offs must be assessed if considering gaming technologies vs. customised simulation solutions; Risk of negative training effect, especially in terms of tactile response in COTS controllers and over-simplified vehicle dynamics, opponent force behaviours, or environmental modelling; Lack of empirical data to determine proper tasks that can be trained in the live/synthetic balance equation; Typical time compression strategies used in gaming applications is inappropriate for realistic training; Lack of SCORM, HLA, or LMS standards compliance. | 9 | 8 | | Offers potential to download training from higher-fidelity (and higher-cost) devices; May be used to practise flying tasks under increasing difficulty levels (i.e., 'automatic levelling') while in-class and under direct supervision, and/or under control of an embedded virtual tutor/intelligent 'coach'; May be used to repeatedly practise difficult procedural areas; May be used to practise subsequent full-mission simulation or flight sorties while at-home (turning slack time into training time); Networked gaming and simulation may be used for team training purposes (e.g., multi-ship formation procedures, etc.). | 7 | LOW | 9 | LOW |
| 13. MICRO-SIMULATION SYSTEMS (Reference Section 13) | | Offers similar advantages to high-end simulation; Can be used to practise training tasks repeatedly, using equipment less expensive to operate than live equipment, but more affordable than the next level of full mission simulation (and perhaps more cost-effective than lower-level cockpit procedures trainers or part-task training devices); Can be configured to integrate with existing CBT, to provide standardized training content to users; Can be used to assess trainee performance; Easy to install, inexpensive to maintain, and replacement decisions involve simple throwaway factors. | Cannot compete with high-end simulators in terms of synthetic fidelity; Increased risk of negative training effects in terms of tactile and/or psychomotor responses; Physical environment may be inadequate for the training task requirement; Students may require specific training in micro-simulator operation, potentially wasting valuable training time or creating additional negative learning effects; Single-monitor systems may create poor habit patterns (e.g., inability to employ peripheral vision, poor instrument-to-visual scans, etc.); Lack of motion feedback may result in disorientation, possibly exacerbated in the live training environment; Moveable, but lack of portability limits usefulness. | 9 | 8 | | COTS systems offer high potential to download training from higher-fidelity (and higher-cost) devices; Cost factors may allow deployment in greater numbers, to wider targets of students, from acquiring basic knowledge to practising specific flying tasks while in-class and under direct supervision, and/or under control of an embedded virtual tutor/intelligent 'coach'; May be used to repeatedly practise difficult procedural areas, to practise subsequent full-mission simulation or flight sorties while at-home (turning slack time into training time); Networked gaming and simulation protocols may be optimised for team training purposes. | 7 | LOW | 9 | LOW |
| 14. PERSONAL COMPUTING SYSTEMS (Reference Section 14) | | Offers ability to improve user-level training interaction, learning ability, performance, and overall training experience for students, instructors, and staffs; High-resolution displays permits export of higher-order training to classrooms or at-home desktops (slack time becomes training time), with adequate fidelity to support/potentially download high-level training tasks; Offers portable solutions for administering/receiving training materials anywhere, anytime; Instructor/student ratios can be altered as administration ability is improved; Provides means to quickly disseminate information. | Price is typically twice that of desktop alternatives; System weight may not truly represent a portable solution (especially if peripherals are required); Inadequate battery life; Limited connection ports; Limited CPU speed/memory capacity issues; Displays are smaller than desktops, limiting usefulness for training tasks that have high real-estate requirements (e.g., full instrument panels, etc.); Upgrades can be costly and, in some cases, not possible due to portability design limitations; Limited sunlight-readable displays; ease of use (e.g., PDA data input). | 9 | 8 | | Reduced need for paper-based training materials; Export appropriate coursework to electronic media to enable distributed learning & assessment strategies, configuration management & control, efficient update mechanisms, or reduce need for dedicated classrooms/required trainers; Using mobile delivery strategies, move training to work locations, enabling an "I see, I retain" learning paradigm, or minimise error rates due to double-journaling; Provide ready access to accurate electronic reference data; Provide after-hours access to learning materials; Increase efficiency of training administration tasks. | 7 | LOW | 9 | LOW |
| 15. MOBILE COMPUTING and WIRELESS NETWORKING SYSTEMS (Reference Section 15) | | Provides access to real-time data for improved decision-making; Permits faster and more accurate decisions; Improves productivity by moving staffs away from desktop environments to actual work locations; Reduces error rates caused by double-journaling; Offers potential to convert slack time into productive time; Relatively low system implementation cost and simple expansion as requirements grow; Rapid deployment capability; Eliminates need to hard-wire physical structures; Provides rapid dissemination of training information, including operational data (e.g., changed schedules, new training materials, etc.). | Wireless data transfer rates remains problematic, especially where a single wireless node is in place for mobile applications; Mobile equipment suffers from battery life issues, which limits ability to complete assigned work in any mobile network implementation; Mobile workers will (inevitably) move out-of-range of the wireless access points; Insufficient signal strength or microwave interference will prevent stable communications; Self-configuring protocols are needed in mobile equipment where large-scale wireless networks with (typically) thousands of micro-cell nodes; Wireless networks remain a data security risk. | 9 | 4 | | Enables reduced need for paper-based training materials, coursework exported to electronic media to enable distributed learning & assessment strategies, configuration management & control, efficient update mechanisms, or reduce need for dedicated classrooms/numbers of trainers required; Using mobile strategies, move training to work location, enabling an "I see, I retain" learning paradigm, or minimise error rates due to double-journaling; Provide ready access to accurate electronic reference data; Provide after-hours access to learning materials; Increase efficiency of training administration tasks. | 5 | MEDIUM | 6 | MEDIUM |
| 16. EMBEDDED TRAINING SYSTEMS (Reference Section 16) | | Offers ability to utilise operational equipment in the operational environment; Provides a means to practise skills when live ranges or adversaries are unavailable; Depending upon the application, may permit training of multiple students in a single mission sortie; Minimises concurrency issues with live training equipment not current with the operational equipment; All benefits of simulation are present in the live environment; May allow portions of operational conversion or front-line training to be downloaded; May re-use software applications developed for simulation training purposes. | Opportunity to maximise training potential may be limited by reduced numbers of live equipment fitted with embedded training systems; May require considerable development and testing cycles where there may be an impact on flight safety or aircraft certification; Ability to employ training modes in operational systems may impose risks of inadvertent emissions or impacts on flight-critical software; Where operational equipment are dual-purposed as training equipment, training capability may be limited to the system or sensor features of the host equipment. | 9 | 9 | | Reduce reliance on live adversaries/ranges by providing virtual targets for training purposes; Download tasks previously performed at the Operational Training Unit; Introduce concepts & tasks earlier in the training continuum; Increase effectiveness of live training across both individual/conjoint training requirements by maximising live training expenditures; Provide cost-effective training without need to procure expensive equipment for training platforms (e.g., embed simulation of operational radar on training aircraft - without need/expense to procure and/or retrofit training platform with real equipment). | 7 | LOW | 9 | LOW |