Appendix C

Forecasting Tables

These tables are the result of brainstorming by the Panel members during the summer study. The goal of the session was to identify the most significant happenings in each of the focus areas and explain why they were significant to the Air Force. Several focus areas did not get discussed due to time constraints.

Communications

What?	When?	Why Important?
Most important applications for comm are surprises to authors of this report and to everyone else.		History shows that, although we can predict infrastructure, ***we cannot predict applications***; don't use today's applications to plan future needs for capacity.
Data traffic on all nets continues to double annually.	**1995-2010**	Fundamental law of nature; enables projection of capacity requirements in spite of unknown applications.
Global commercial optical networks, 10Gbps per wavelength, per fiber, wavelength division multiplexed.	**2000**	Ultra cheap ultra-high-speed backbone gives essentially infinite bandwidth.
Broadband commercial satellite network (>1Mb) (e.g., Teledesic)	**2005 (.5 probability)**	Commercial broadband comm in remote regions.
At least one global commercial satellite telephone network exists (e.g., Iridium).	**2000 (.8 probability)**	Limited capacity voice comm available everywhere.
Widely available commercial wireless infrastructure in developing nations.	**2005**	Usable commercial infrastructure almost everywhere for voice and low data rates.
ATM becomes standardized broadband environment.	**2000**	COTS availability of broadband computer comm equipment.

What?	What?	Why Important?
IP v6 (or vx) is standard computer protocol.	**2000**	Commercial basis for real time signals (e.g., video conferencing) on packet nets, policy-based routing, security, and expanded address space.
Internet as global information infrastructure .5B people connected using cheap, ubiquitous "Internet phone/data appliance."	***2000-2005***	*Overarching, super-national civilian connectivity profound social, business and military consequences; intel consequences.*
Computer network warfare	**2000 (depends on investment)**	Delicate balance between network attacks and defense; critical differentiator
World Wide Web becomes collaborative, with virtual reality, interactive, point-of-view browsers.	**2000**	This will enable the AF to find new ways of conducting its business and operations.
Number of large companies decreases and virtual companies multiply because of networks.	**2000**	AF may have to remodel itself organizationally in radical fashion.
Commercial comm facilities become cheaper by factor of 10 (Over and above normal price decline of 11% annual) because of adoption of Internet paradigm with complexity and cost at periphery.	**2005 (.4 probability)**	Makes AF comm facilities that don't rely on commercial facilities uneconomical.
Instant broadband wireless infrastructure; wireless LANs, deployable distributed wireless self-organizing nets.	**2000 (depends on investment)**	Deployable broadband infrastructure.
Unattended autonomous vehicles used to fly patterns for comm relay.	**2005**	Good solution to the 100-mile gap between forward units and commercial gateways.
Broadband comm links into tactical aircraft provided by satellite.	**2005**	Bandwidth for sensor telemetry and commands to the smart or remotely piloted vehicle.

What?	When?	Why Important?
World standards for encryption with wide commercial usage.	**2000-2005**	Unbreakable codes for both sides; military can use commercial security packages.
Agents negotiate QOS (Quality of Service) across heterogeneous nets.	**2000**	Buy just what you need for a given application (e.g., video) from multiple vendors.
There is a breakthrough by a factor of 10 in compression efficiency.	**2000-2005**	Demands for bandwidth will eat up the gain.
Multimedia queries can be accessed by content.	**2000-2005**	Find pictures and sounds by description of content.
Global knowledge banks codify "knowledge" in many fields.	**2000-2005**	Better than libraries or databases.
Electronic agents, filters, and communications surrogates mediate communications.	**2000**	More efficient communications — electronic "secretaries."

Human-Computer Interaction

Computer uses are so broad and definitions and perceptions of functionality so user-dependent, that development metrics such as degree-of-intelligence are very difficult to define. So, the development of human-computer interaction should be thought of principally as a direction and not an end. (Dates are 2-4 years after introduction to commercial marketplace.)

What?	When?	Why Important?
Intellectual Support		
Natural language understanding - (Text, speech, writing and gesture recognition plus understanding but separately employed.)	**2000**	- Ultra-mobility - Hands-occupied operations - Task-specific needs
Modality integration - (All interaction components taken in combination appropriate to situation.)	**2002**	- Task adaptation - User preference adaptation
Task-oriented commands - (Interaction above present application level. Context-aware tasking and execution.)	**2005**	- Work-centered, context-aware interaction combining the offerings of present-day applications programs - Visual programming at task levels
Delegation - (User-like understanding and reaction to tasking, dialogue)	**2010 (w/investment)**	- Task machine in natural language to carry out goals - Intuitive, training-free interactions; one-session results
Hardware: - Displays: -- Flat, low power, print-quality (300 dpi ATLC) -- Wall (projected) with arbitrary resolution -- Bright, flat, high resolution, low power	**1998**	- For desktop and mobile applications - Projected wall-size seamlessly tiled displays with very high, "walk-up-to" resolution

What?	When?	Why Important?
- Scanners - smart paper (encoded background)	**1998**	- Tells scanners details of digital page conventions.
- Speech - Continuous, speaker-independent, 1-2% error rate, correctable with context	**2004 (w/investment)**	- Speech and handwriting modules available and affordable in server, workstations, PCs, etc. User toolkits.
- Handwriting - (same as speech)	**1997**	
- Video conferencing - (See Communications.)	**2000**	
Virtual Reality		
Totally synthesized environments that are sensory-matched to human capabilities. Consists of head-mounted stereo visual and aural presentation, a tracking system, a controller, and a haptic output.	**2005**	- Visualization of other, altered worlds - Training scenarios/simulation [Caution: until sensory mismatches are corrected, VR systems may cause sickness under long term use]
Hardware - Displays - Need head mounted, 3D, very high resolution (~10^{10} pixels), object-specific focusing (Display not fixed focused) - Trackers - Need 6D wireless, low hysteresis - Controllers - Need speech recognition, gestures	**2005**	- Entertainment market may deliver affordable versions.
Augmented Reality		
Overlaying synthetic cues and structure over real-time, real-world activity. May require transparent, but imaging glasses and some tracking system with spatial synchronizing of real and synthetic images or a projected spatially synchronized overlay on the target object.	**2005**	- Training, performance evaluation - Maintenance tasks - Hazardous undertakings - Simulations - Constraints/enhancements can alter real capabilities

What?	When?	Why Important?
Hardware - Requires transparent glasses which are also displays. - Trackers - Need to be an order of magnitude more accurate than VR trackers, depending upon distance separating real and overlaid image.	**2005 (w/investment)**	- Rapid advance of inductees' skills alone would be very profitable in above roles. Fewer airmen to carry out increasingly technical roles. This technology may not get developed by the entertainment industry.
Telepresence Real-time/human sensing and physical dexterity are translated into inaccessible spaces.	**2005 (w/invest) (evolutionary)**	- Remote operations (some delay-bounded): RPVs, surgery, hazardous ordnance, viewing and sensing,.... - Motion translation: minimally invasive surgery, - Scale transformations: microsystem assembly/repair, satellite and space-station repair - Distributed conferencing with extremely high realism

Information Access Technology

Definition: Data to Information flow support.

Situation awareness and decision support:

Post sensor, public, intel data acquisition. Pre display and HCI.

Supports smart processing technologies as Planning, S&M, ...

What?	When?	Why Important?
Information integration:		
Support mission planning	**2000**	Mission execution, rapid replanning
Support analysis of multiple future courses of action	**2010**	
Dynamic integration of actual events, replacing projections with facts	**2015**	
Image indexing technology: obtaining and selecting relevant intel information (spatial, temporal selection) *semantic contribution to indexing.	**2005 (some COTS, costly technology)**	Volume of image-based input growing. Helps *avoid information overload.*
Data reduction by intelligent selection and compression (delta transmission) for limited bandwidth links.	**2005**	Reduce bandwidth for the last 100 miles, build on COTS model based compression research.
Composable software to process information	**2000 (within one standard), evolving**	COTS and standards acceptance dependent.
Architecture for rapid composition of information systems with broad access capability.	**2015 (improvable by investment)**	COTS, but focused on uni-directional interoperation
Tools	**2005**	Verification (OT&E) of information flow for reliability, trust, etc.
Mediators: a form of service agents (SW nodes, people for maintenance) to process potentially relevant information to create value for customers.	**2000 (and evolving)**	

What?	When?	Why Important?
Security mediators - owned by security officers, serve as intelligent gateways.	**2005 (and evolving)**	Needed to interoperate among domains at differing security levels.
Facilitators: locate potentially relevant information, from public and commercial (non-secure) sources.	**2005 (Internet) 2015 (arbitrary nets)**	Needed to exploit all available resources, some DoD adaptation.

Intelligent Software Agents

Intelligent agents:

Are subordinate to a user or owner.
Have degrees of autonomy.
Are goal and not means driven.
May replicate themselves.
May have only qualified roles in safety-critical situations.
(Dates are 2-4 years after introduction to the commercial marketplace.)

What?	When?	Why Important?
Agents by Type		
Directed-action agents ("Do-this" agent) - Has fixed goals but can react to the data and data sources it encounters. Example: Uses the relational WWW search sites and routines to retrieve stated objects (subjects).	**1997 (evolutionary)**	- Retrieve information in a well-indexed world - Sorting information flow - HCI assistance such as speech or network access - Framework for modularized intelligent systems - Collaboration with fixed goals and guidelines
Reasoned-action agents ("Achieve-this"agent) - Has fixed goals and is able to monitor other objects (data and processes). It can also reason about what it "sees" and take appropriate action. Continuing with above example: also examines the relationally derived sources and evaluates source attributes according to general guidelines. May prioritize sources given subject and recall for future use. Negotiates under strict rules.	**2000-2005 (evolutionary)**	- Advisory agents for evaluation and training - Planning agent - Personal assistant that reasons; i.e., an HCI facilitator for a group of directed-action agents - Information probes - Gives system resilience or fault recovery - Heterogeneous database media tion - Agent collaboration with task-sharing

What?	When?	Why Important?
Learned-action agents ("Accept-this" agent) - Has above capabilities plus accepts more general goals and is capable of altering or adding to them under guidelines. Continuing with above example: accepts general direction for information assistance; infers recent user interest in given subject; sets goals for possible information retrieval in that subject; sets up indexing to relevant WWW sources as well as locally created citations. All this to anticipate user need.	**2005-2015 (evolutionary)**	- Very abstract tasking - Personal assistant that has broad awareness from both operations and its own probing - May use guidelines and inference to set new goals - Agent collaboration with dynamic task sharing - Context-sensitive help in HCI - May facilitate or manage a set of direct action or reasoning agents
Agents by Functionality		
Advisory agent - Able to evaluate human or system performance in a circumscribed, application-specific framework and make corresponding recommendations and perform goal-seeking actions	**1997-2005 (evolutionary)**	- Teaching and training aids - Planning systems - offers tomorrow's trial ATO - Monitors maintenance records on jet engines to predict need for major overhaul or replacement - Manages parts arrival in just-in-time scheduling
Personal assistant - Will handle many HCI tasks like email, conferencing, interaction modalities, information filtering, scheduling, etc.	**2000-2005**	- Handles many well formatted and unambiguous tasks - Finds and reserves next available flight
Offers a broader representation of the user in permitted jurisdictions.	**2000-2005 (evolutionary)**	- Calendarizes some user activities - Monitor and approve movement of consignments

What?	When?	Why Important?
Traveling agent - Can transparently retrieve well-defined information from a variety of distributed sources [Relies on consistent library interfaces]	**2000-2005 (evolutionary)**	- Retrieves well-indexed information given indices or well-defined subjects [Caution: As much as 90% of all stored data is in unstructured form and perhaps irretrievable.]
Eventually learns retrieval environment itself for subjects of stated interest. Decides whether to use remote or user's cycles (host) in pursuit of goal.	**2005-2010 (evolutionary)**	- Information awareness and retrieval with user-defined guidelines - Heterogeneous database mediation
Will provide broad and transparent representation for all well-defined user transactions, filtering information streams for user interests.	**2010-2015 (evolutionary)**	- Formulates and remembers preferences - Avoid safety critical situations
Collaborating agents- Multiple, function-specific agents form basis for intelligent systems. The simplest act at the behest of a facilitator or coordination agent, the more intelligent work out task sharing, and the most intelligent do dynamic task sharing to meet goals.	**2005-2010 (evolutionary)**	- Modularization of computer-based systems - Deliver integrated functionality for HCI - In a distributed computing world, monitors operations to "learn" how crashing occurs, what processes are affected, and how to recover - Basis for pilot's virtual associates
Design methodology for intelligent system design, including how intelligence is distributed in a system and the most appropriate abstraction for component interaction.	**2010 (evolutionary)**	- A framework for intelligent, distributed system design - Used in graceful degradation or fault tolerance where multiple functions exist

Artificial Intelligence

What?	When?	Why Important?
Natural Language Understanding:		For ease of use and broad applicability of computers.
95% in specialty areas	**2000**	
95% in areas of common knowledge and culture	**2010**	
95% across breadth of human experience	**2015**	
Knowledge Web of tens of millions to hundreds of millions of pieces of knowledge, distributed over Internet.	**2005-2015**	Enabler for Intelligent Applications e.g., critical mass for modular learning e.g., intelligent systems with common sense.
Inflection point in knowledge acquisition, learning, adaptivity by logical and heuristic methods.	**2005-2015**	Because of its relation to domain-specific software tools, predict order of magnitude increase in speed of software development, for example for training, intelligent agents, and data fusion.
Synthesis of neural nets and symbolic reasoners.	**Evolving**	Use neural nets for pattern recognition and symbolic reasoners for understanding.
Learning based on evolutionary models.	**Slowly evolving**	No miracles.
Plausible, "soft", inexact, fuzzy, probabilistic reasoning methods will dominate traditional formal logic and perhaps all other forms of computation.	**2015-2220**	Most problems that computers will be assisting with are not exact, numerical, or Boolean (black-or-white). Example uses: battle mgmt. and planning, sensor fusion, decision support, risk mgmt.
Signal + Symbol information fusion	**Depends on effort but needs ACTD**	Situational assessment.
Design rationale management	**Evolving**	Makes redesign and maintenance both feasible and affordable.

Planning and Scheduling

What?	When?	Why Important?
Basic plan rationale capture.	**2000**	Semi-automated case-based trans. and force planning. Semi-automated plan modification One COA.
Advanced plan rationale capture.	**2005**	90% automated plan selection and modification, based on planner's goals; multiple COAs.
Decision theoretic control of inference.	**2005**	Adaptive planning in uncertain environments.
Modeling and simulation advances.	**2010**	Campaign planning via detailed simulation.
High speed constraint-based scheduling.	**2000**	Order of magnitude increase in speed of scheduling from TPPFDs.
Rationale-based schedule repair.	**2005**	Fast, high-level modification of schedules.
Coordinated multi-agent planning.	**2000**	Automated planning that takes into account multiple perspectives.
Concurrent multi-agent planning.	**2005**	Order of magnitude faster multiple perspective planning.
Continuous, mixed initiative planning teams.	**2010**	Planning as a continuous around the clock process, constantly updated by a team of people and software agents working together.

Modeling and Simulation (M&S)

What?	When?	Why Important?
Modeling and simulation interoperability - Basic: data definitions, declarative protocols, 2 levels. - Advanced: assumption reconciliation, multilevel dynamics, advanced media.	**Basic- 2005 Advanced- 2015**	Ability to capitalize on multiple M&S's for combat systems definition and acquisition, test, production and logistics, education and training. Requires continuing evolution of interoperability standards and conventions, application to M&S.
User languages for M&S generation and analysis. - Basic: Assembly with simple interoperability support. - Advanced: Automatic M&S configuration based to satisfy user goals.	**Basic- 2005 Advanced- 2015**	Rapid, flexible composition of complex M&S.
Believable semiautomated forces (SAFOR) for full combat spectrum. - Basic: reactive to current state, based on simple heuristics. - Advanced: complex heuristics; learning capabilities.	**Demo quality- 1995 Basic- 2005 Advanced- 2015**	Cost-effective M&S salability. Enable experimentation with doctrine and strategies.
Virtual system acquisition: flexible migration from virtual to actual system capabilities.	**2015 - for mature domains (e.g. mainstream aircraft, missiles, spacecraft). 2025 - for complex domains (e.g. integrated combat systems including C^3I, battle management).**	Rapid, flexible acquisition of pre-exercised systems. Complementary closed-loop exercise and evolution of system and its M&S support. Requires strong M&S support, revised acquisition procedures, virtual competition ground rule, education.

What?	When?	Why Important?
Defense simulation Internet: Network support of “Louisiana Maneuvers” scale activities.	**2000 - occasional-exercise support 2010- regular use**	Network infrastructure for theater-level simulations, virtual reality.
M&S verification, validation, and accreditation. - Basic: Test suites, simple assertion checking. - Intermediate: Simple domain-model and built-in-test checking. - Advanced: Agent-based domain model checking and dynamic built-in test.	**Basic- 1995 Intermediate- 2005 Advanced- 2015**	Critical to M&S credibility. Requires significant investment concurrent with M&S development and upgrade.

Software Development Technology

What?	When?	Why Important?
Powerful User Programming. Over 50% of workforce able to harness packages with millions of lines of code in a few hours to accomplish a semi-custom design.	**Corporate information management: 2005 Combat systems: 2005-2015 (depending on investments in domain engineering)**	Users get the software they want right away (for straightforward applications). Requires education, safety control limits on user programs, another level of application interoperability conventions to be able to bring user program together.
Concurrent engineering of devices and their software through integration of CAD, CAM and CASE.	**2005-2015**	Better allocation of functions to hardware, software, people. Moving software development to earlier in the product cycle. Requires bringing together physical models and computing models. Treating software as a first-class system design element.
Adaptive software: systems that automatically improve themselves based on observation of usage and data patterns.	**2005: used by > 50% of Fortune 100 companies**	Rapid, cheaper, more assured software adaptation to changing situations (e.g., Serbian mobilization patterns). Requires countermeasure defenses.
COTS software componentry and CASE tools enhanced to meet Air Force combat needs: security, survivability, real-time performance, scalability.	**Continuing**	Air Force combat software needs satisfied by commercial capabilities. Requires pro-active Air Force and DOD COTS software evaluation, enhancement R&D, and stimulation of commercial enhancements.
Commercial penetration of ADA will continue to be low, due to C/C++ COTS critical mass.	**Continuing**	Requires ADA/COTS bindings and interoperability packages.
"Beyond-Object-oriented" programming language better than C++ will be developed.	**2005**	Opportunity to support more disciplined and flexible software engineering.

High Assurance Systems

What?	When?	Why Important?
Highly penetrable - Military Systems - Civilian Infrastructure	**NOW**	We are vulnerable, but basic solutions exist.
Cryptography routinely embedded transparently.	**2000**	AF Key policies should be developed. Key escrow should be used because cryptography will be unbreakable, attack points will shift (e.g., Human/Protocol).
Cryptography uses expand.	**Slow Evolution**	Most effort should be in integration of use.
Theory	**KEO**	If P=NP, new encryption methods will be needed.
Molecular Computation Quantum Computation		New models of computation may arise.
Embedded Multi-Source Biometric Identification.	**2000**	Basic security embedded in terminals, etc.
Unobtrusive Ubiquitous Continuous biometric identity.	**2010**	“Smart locks” widely available.
Basic Survivability Via Dispersal.	**Now**	One contribution to high assurance
Graceful degradation.	**Depends on investment**	Load balance between man and machine. Redundancy between man and machine (Optimization and degradation are opposed).
Rules of Engagement.		There are none, policy needed!

Organization and Education

Organization is a differentiator.
Conflicts are organizational phenomena.
Developments are non-discrete.
IT will change AF independent of IW mission (e.g., airpower).
Severe organizational culture limitations (e.g., IBM mainframe).

What?	When?	Why Important?
Paradigmatic organizational change e.g., flat architecture, beyond virtual reality.	**2015**	Assessment, control, etc.
Emphasis shift away from top down to become adaptive.	**2005**	Education, personnel systems, IW mission.
Profound educational change.	**2010**	Selection, continuing education/ training.

Open questions:

On-going process suggestions.
Enablers or other structural techniques.
Is the Air Force a reasonable organization to compete in this mission.