The Tactical Life Support System (TLSS): Precursor to *Combat Edge*

By Christopher T. Carey

At the present time (2001) all high performance combat aircraft pilots in the US Air Force use a life support system known commonly as simply "CE", or "Combat Edge". As it is found in today's front line F-15 and F-16 fighter aircraft, the system consists of a specially configured helmet and mask (HGU-55/P-CE and MBU-20/P), an associated counter-pressure breathing vest (CSU-17/P), a CRU-94/P connector, and utilises the standard CSU-13/P anti-G lower extremity garment.

The story of how the present system came into being is not only inherently interesting, but important in that it illustrates the process whereby advancements in life support technology are based upon and in part drawn from technology already proven in lesser known precursor studies such as the TLSS program of the mid to late 1980s.

The Tactical Life Support System was the first US Air Force 6.3 Advanced Development life support program. That is, it was the third phase of the four phase categorizations that have been established by USAF for all materiel acquisition and funding activities. [Phase 1 is "Basic Research"; Phase 2 is "Exploratory Development"; Phase 3 is "Advanced Development"; and Phase 4 is "Engineering and Manufacturing Development".]

The TLSS program had a wide range of research objectives that included NBC (nuclear, biological, chemical) protection, advanced anti-G protection, moderate high-altitude protection, anti-flash eye protection, aircrew cooling and personal conditioning, and on-board oxygen generation (via molecular sieve apparatus). Due largely to the daunting task presented to researchers of integrating effective levels of satisfactory function in all these complex areas into a single system, the TLSS never reached fully operational status. The most important contribution of the TLSS studies, however, was extensive research testing of several aspects of the TLSS objectives that were incorporated into the present Combat Edge system. TLSS program technology has also contributed substantively as a foundation for several present areas of life support research.

Before the TLSS program was fielded, there was no prior life support program which had been able to successfully move through all 4 phases of the acquisition and funding model. Thus another important objective for TLSS was to establish and complete this objective, which it did. Thus, in addition to development of actual systems hardware, TLSS demonstrated the process model wherein life support equipment could be made fully flight-worthy.

As mentioned above, the goals set forth for the TLSS were broad and complex. Among them were pressure breathing for G protection to +9G, limited environmental decompression protection for safe descent from high altitudes as great as 60,600 feet, NBC protection from particulate and aerosol agents, nuclear flash protection (PLZT visor), aircrew cooling and conditioning (liquid cooling system), laser visual protection, and interfacing with an on-board aircraft oxygen generation system of the molecular sieve type (acronym: OBOGS). Many completely new items of equipment had to thus be designed and flight tested in order to fully meet these requirements, including a new breathing regulator that could interface with the aircraft OBOGS, a new type of electronically sensing G-valve for instantaneous G-suit inflation. Additionally, all of these systems had to be configured for continued operation in the event of OBOGS failure or emergency egress at altitude.

Items on the so-called "man-side" of the system included an entirely new and light-weight helmet and oxygen mask system, the former capable of providing cranial protection without additional weight, and the latter able to provide and sustain high pressure oxygen breathing capability in high-G (+9) combat flight profiles. Additional challenges to the USAF, Boeing, Gentex, and Canadian Defense and Civil Institute of Environmental Medicine engineering teams involved original configurations of NBC, cooling, nuclear flash, NBC, and protective garment systems. It should be noted here that the Canadian Defense and Civil Institute of Environmental Medicine was actually responsible for design of the TLSS G-suit garment and actually constructed the first integrated TLSS flight garment, albeit in close cooperation with Gentex and the Boeing company, as Canada had earlier identified the need for suitable high altitude protection for its aircrews when a new high performance aircraft had been selected (subsequently, when Canada settled on the F/A-18, with no substantial high-altitude capabilities, this need was abnegated).

Upon successful completion of initial designs, integrated into test configurations, actual flight testing began at Edwards Air Force Flight Test Centre in 1986 and extended through 1987. A fully integrated TLSS prototype system (including OBOGS) was tested in the front seat of an F-15B aircraft (4 pilots flew a total of 26 flight tests that ranged from familiarisation, through high altitude, air-to-air, and air-to-ground roles), and a simplified system was tested in the aft-seat of an F-16B (24 flight tests, predominantly in air-to-air mode, using the modified CRU-73 regulator and existing valve). It is reported that all pilot evaluations carried out during these tests of the fully integrated TLSS were 'highly' favorable and the recommendation was made for operational development. Among the test modes explored during the integrated TLSS system (F-15B) flights, an actual 28,000 foot explosive decompression test was carried out, although a 60,000 explosive decompression test was carried out only in an altitude simulation chamber. While pressure breathing safely provided support between 25,000 and 39,000 feet, a maximum mask/torso pressure of 70 Torr was maintained. At extremely high altitude, the G-suit pressure reached was 4 times the 39,000 foot breathing pressure.

The aspect of the completely integrated TLSS system most praised in the fully integrated TLSS system was the substantially improved protection provided the wearer during accelerated, extreme G maneuvering. As these benefits came into clearer focus, several somewhat simplified combinations of various TLSS components were subsequently developed and then flown in an F-16B aircraft. One such simplified system used the CRU-73 breathing regulator that was specially modified to provide pressure at high-G. The success of these modified and somewhat simpler systems resulted directly in a redirecting of the TLSS program's central goals towards improved G-protection.

This redirection in the TLSS program was further spurred on, in 1988, by the great incidence of G-LOC (Gravity Induced Loss of Consciousness) caused accidents in high performance aircraft such as the F16 Viper. This in turn resulted in headquarters of Tactical Air Command issuing a formal request for an accelerated advanced pressure-breathing G system that could be retrofitted to all existing aircraft.

Thus, the wheels were now set in motion for a secondary drive towards using technology designed for the TLSS program to develop a simpler, but very effective pressure-breathing anti-G system for immediate application to USAF's high performance fighters (F-16, etc.). With this new directive emergent, a new phase of centrifuge studies was initiated with several combinations of components from the wholly integrated TLSS system to explore this requirement. Several aspects of TLSS that were included in this new investigation were use of the integrated garment approach (counter-pressure upper breathing garment combined with lower anti-G garment), enhanced existing G-suit coverage, and a very low-resistance breathing system. Chief concerns voiced included questions as to how this modularization of the integrated suit would possibly compromise chemical agent protection.

The breakdown into modular system proposals took the following form: Ensemble I, with TLSS Fully Integrated Pressure Vest torso garment (upper garment, or UPG), TLSS Extended Coverage Suit (lower garment, or LPG), and Modified CRU-73 oxygen regulator; Ensemble II, with TLSS Component Pressure Vest torso garment, standard CSU-13/P anti-G suit, and modified CRU-73 oxygen regulator; Ensemble III, with Extended Pressure Vest torso garment, CSU-13/P anti-G suit, and modified CRU-73 oxygen regulator; Ensemble IV, with Extended Pressure Vest torso garment, Full Coverage anti-G suit, and modified CRU-73 oxygen regulator; and Ensemble V, with Extended Pressure Vest torso garment, Full-Coverage anti-G suit, and NGL low-resistance oxygen regulator. Each of these 5 component alternative system proposals used the TLSS oxygen mask and helmet and centrifuge studies were conducted on a 5-9 G SACM (Simulated Aerial Combat Maneuver) acceleration profile (to exhaustion, using the F-16 semi-reclining ACES II type ejection seat).

6 volunteers wore the 5 different systems to compare the efficacy of the 3 modular torso counterpressure vest garments against the two full torso models. Ensemble I used the integrated TLSS coverall, with its upper pressure garment (UPG) and lower pressure garment (LPG), which was about identical to the use of the UPG in combination with the standard CSU-13/P anti-G suit. The full coverage anti-G suit teamed with the 'extended pressure vest' in ensemble 4 to provide complete and uniform circumferential pressure coverage to legs, feet, and abdomen, while Ensemble 5 used an experimental (NGL) UK pressure regulator that while providing the same pressure parameters as the CRU-73, offered lower breathing resistance.

Based upon results emerging from these centrifuge tests of the 5 basic models, combination number 3 (extended pressure vest, CSU-13/P anti-G garment, and modified CRU-73 regulator) was chosen as the baseline model for development of the new *Combat Edge* (formally known as the Combined Advanced Technology Enhanced Design G-Ensemble) system. While the full coverage anti-G suit significantly increased G-tolerance, this suit (now known as the ATAGS, or Advanced Technology Anti-G Suit) would remain under study for further development and possible use in future systems. It was envisioned that the ATAGS would eventually replace the existing CSU-13/P “speed jeans” system, if the further ATAGS studies proved favorable. Among changes to the new CE system, it was recognized that the CE regulator would have incorporated into it the low-resistance, high-flow capabilities that had clearly been shown to be preferable.

With this *Combat Edge* program splintering off from the TLSS program, several further changes came into effect. The TLSS helmet and oxygen mask system would be modified for CE, resulting in use of the standard HGU-55/P helmet in which an occipital bladder was installed, and slight modification of the TLSS mask system to reflect smaller, lower-profile connections to the bladder than had existed on the TLSS mask. The two masks, were, in virtually every other respect, quite similar to each other, except for various small changes in the components. The new mask would be designated the MBU-20/P mask, a variant of which that was identical, except that it lacked the occipital bladder, being designated the HA/LP 02 mask. Finally, the developmental extended counter-pressure breathing vest of Ensemble III would be reconfigured into a new design designated the CSU-17/P vest and standardised for production. Finally, the new *Combat Edge* system would use the current CSU-13/P anti-G garment already in use on F-16 and F-15 aircraft.

Combat Edge man-rating was completed in 1990. Operational testing and evaluation was completed in 1991. F-16 system acceptance for extended follow-on operational validation was completed in 1993. Full F-16 retrofitting for CE was completed in 1994. All F-15 aircraft modifications to assure Combat Edge compatibility was finished as of mid 1995. F-15 “man-side” equipment was completed in 1996. Today, all new F-16s are delivered with complete CE interfacing. The F-15E *Strike Eagle* is also delivered with complete CE systems capability.

Combat Edge is now in standard service use for all missions requiring high-performance aircrew G-protection.

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REMARKS:

While the TLSS system itself was not developed into a fully operational system for standard use, much of the work done in that program has been extremely useful as foundation for further levels of development. A version of the *Combat Edge* system that would be hardened against chemical agent threats has been designated *Combat Ace.* Many concepts and component systems developed in TLSS have gone on to form the foundation for the F-22 ALSS (Advanced Life Support System), which is continuing. One of the reasons why the TLSS was not adopted was due to the fact that the ‘acquisition’ community felt that the cost was too great; this was a feeling that existed at the time the Combat Edge system, with its emphasis on anti-G protection’, splintered off from the TLSS program. One view expressed the opinion that although the TLSS was not completely ready for adoption, after the CE development was accomplished and the immediate anti-G protection need satisfied, the TLSS could be completed to meet all program objectives. This turned out not to be the case and the TLSS program as such ended, and served instead as the R&D foundation upon which the following systems would be based.

The new F-22 life support system, a complex follow-on to TLSS and CE, as of 1995 mandated an On Board Oxygen Generation System (OBOGS) using a three-bed molecular sieve system, a new Breathing Regulator and Anti-G Valve (BRAG) designated the CRU-109/A, use of the existing CRU-94 ITB (from *Combat Edge*), an Upper Pressure Garment (UPG) designated the CSU-18/P, and a Lower Pressure Garment (LPG) designated the CSU-19/P (that has been baselined off the ATAGS program (both the UPG and LPG are worn over a standard flight suit).

Also included in the new F-22 system is the HGU-86/P helmet (developed by the UK firm *Helmets, Inc*., in cooperation with Boeing and Gentex), which has improved retention proven for ejections in excess of 600 knots, minimizing lift forces, maximum noise attenuation and universal sizing ergonometry refinements, light weight, enhanced peripheral fields of vision, an improved earcup tensioning system, active PRU-57 Noise Reduction circuitry, and improved mask retention and adjustment receivers. Since the helmet has been designed in combination with the new MBU-22/P mask that is to be used with it, the overall concept is reportedly much advanced in all areas of concentration, not the least of which is achieving greatly enhanced wearer comfort.

Of particular interest is the MBU-22/P mask, which has an automatic mask face-seal tensioning bladder on the front of the mask, whereby the system pushes the mask into the face, unlike the present CE system wherein the face is pushed into the mask by an occipital bladder. Separation of inhalation and exhalation valves achieve a greatly lowered resistance to breathing (something which the combined inhalation/exhalation type valve used on MBU-5/P and MBU-12/P masks could not deliver). A reactive face seal also helps the mask retain pressures as high as the 70 Torr targeted for maximum delivery. With a low profile, low moment of mass, and excellent visibility, the mask also uses the standard M-169/AIC microphone, although it is capable of taking new components as they are developed.

Finally, the system uses an Air Cooling Garment (ACG) type CMU-31/P to achieve thermal loading reduction on the aircrewman, utilising a vest type, open cell, non flammable foam garment that is covered with flame retardant material, through which cooling air is circulated with reportedly great efficiency.

At the present time (6/2001) development is continuing on this system, which is known as the Advanced Life Support System (ALSS).

Another system which developed from the original TLSS program is an independent Gentex proposal, based substantively on the original TLSS helmet and mask set. This system is also known as the *AIR COMBAT SYSTEM*, but it was not adopted by the US Air Force due to problems of compatibility with existing systems. *The Air Combat System* utilises the TLSS helmet and MBU-20/P mask. Since the TLSS helmet system uses a proprietary and unique suspension and occipital air bladder interface, the MBU-20/P mask has been fitted with the necessary connections that the TLSS helmet requires. Instead of the standard TLSS visor attachment, a permanent twin-visor assembly as been fitted that features infinitely adjustable rotary positioning control. Kevlar is used for the shell and the special inner ventilation distribution system that was originally an integral part of the TLSS helmet's NBC protection system has been omitted. The oxygen inlet hose it fitted to the right side of the facemask, instead of the left (as on most CE systems).

The *Air Combat System*, although not procured by the US Air Force, has recently been in limited use among several European nations and the export McDonnell-Douglas F/A-18 aircraft is currently one of the few aircraft that the system is flown in. It is an excellent system, however, being a pure fighter/combat version of the TLSS system in which TLSS chemical protection and anti-flash capabilities have been left off. The *Air Combat System* has also been referred to as the ATLSS, or *Advanced Tactical Life Support System*, although this appellation is incorrect and misleading.

The US Navy today has replaced its own HGU-55/P helmets with the HGU-68/P helmet , which when combined with the MBU-24/P mask is their version of the US Air Force's *Combat Edge* system. The HGU-68/P helmet features a much improved, lightweight, and easily adjusted external visor that has been rocket sled tested at the Talley Hurricane Mesa facility to resist ejection wind-blast forces in excess of 600 KIAS.

AFTERWARD:

Several images of various components of the TLSS system and the *Air Combat System* have been provided as accompanying illustrations. Bear in mind that the TLSS system as originally conceived, had two distinct postures: 1) the chemical agent hardened mode, and 2) the pure fighter air combat mode. The Gentex *Air Combat System* is an expression of what the TLSS would have been, if carried through to a purely air combat level of development. The complete TLSS anti-nuclear, anti-flash (PLZT) mode for helmet and mask is also illustrated. Note the extreme differences in appearance that the chemical and anti-flash accessories impart.

REFERENCES:

Sincere thanks to several individuals are due whose identities are being withheld as a courtesy so as to protect their privacy. Frequent referral was made during the preparation of this summary of developments to the exceptionally interesting and informative syllabus from the 1995 Armstrong Laboratory symposium on high altitude life support and physiological issues (title: *"Raising the Operational Ceiling: A Workshop on the Life Support and Physiological Issues of Flight at 60,000 feet and Above",* coauthored by Dr. William Sears and Dr. Andrew A Pilmanis. In particular, the article in that syllabus by Col. Robert M. Shaffstall, USAF (Ret), Lt. Col. Thomas L. Morgan, USAF, and Lt. Col. Thomas W. Travis, USAF, has been of exceptional use. Information has also been gathered by Alan Wise and Mike Breuninger's book *Jet Age Flight Helmets,* which is always useful (ISBN 0-7643-0070-9, Schiffer Publishing, 1996).

Finally, this article is intended only as a general and very basic overview of what was and remains a very complex area of life support research and development. It is intended only to help clarify in the broadest of terms, how extremely important the original TLSS program was in furthering present day understandings of advanced life support issues in the USA.

Special mention needs to be made of the US Air Force HGU-51/P ICDS (Integrated Chemical Defense System), which was completed and in limited use by the early 80s (a cooperative project with

Gentex), had a substantial impact on the TLSS technology that later drew upon it. Many of the system components, such as the PLSS (Portable Life Support System) also known as the "portapac", were incorporated into the TLSS design with little modification needed. The HGU-51/P lightweight helmet, of a special design that kept the helmet's CG within ½ inch of the wearer's head, also helped point the way towards design of the later TLSS helmet configuration. The ICDS assembly, which incorporated nuclear flash protection (PLZT) in the visor, was extensively flight tested in F-4 and F-15 aircraft by the 3246th Flight Test Wing at Eglin AFB.

The HGU-51/P helmet could also be used in a non-CD mode termed the "Tactical Maneuvering Mode", in which event the innovative new oxygen mask design helped keep the mask in place during high-G circumstances. The HGU-51/P mask comprised the initial LSS design effort to eliminate the awkward "elephant trunk" oxygen hose and figured prominently in initial development of the TLSS system's mask and the final MBU-20/P and HA/LP mask designs.

The HGU-51/P ICDS achieved an integration of several parameters never before attained in previous non-pressurised (i.e. FPS and PPS) LSS ensembles (anti-nuclear flash, NBC protection, and enhanced ACM) and was used to a limited degree operationally in the F-111 *Aardvark* nuclear bomber. One may think of the HGU-51/P system as a design-inspiring precursor to the TLSS concept and as a TLSS conceptual prototype that lacked the upper body counter-pressure breathing system found on the latter system (that was to become the nucleus of the spin-off *Combat Edge* development).

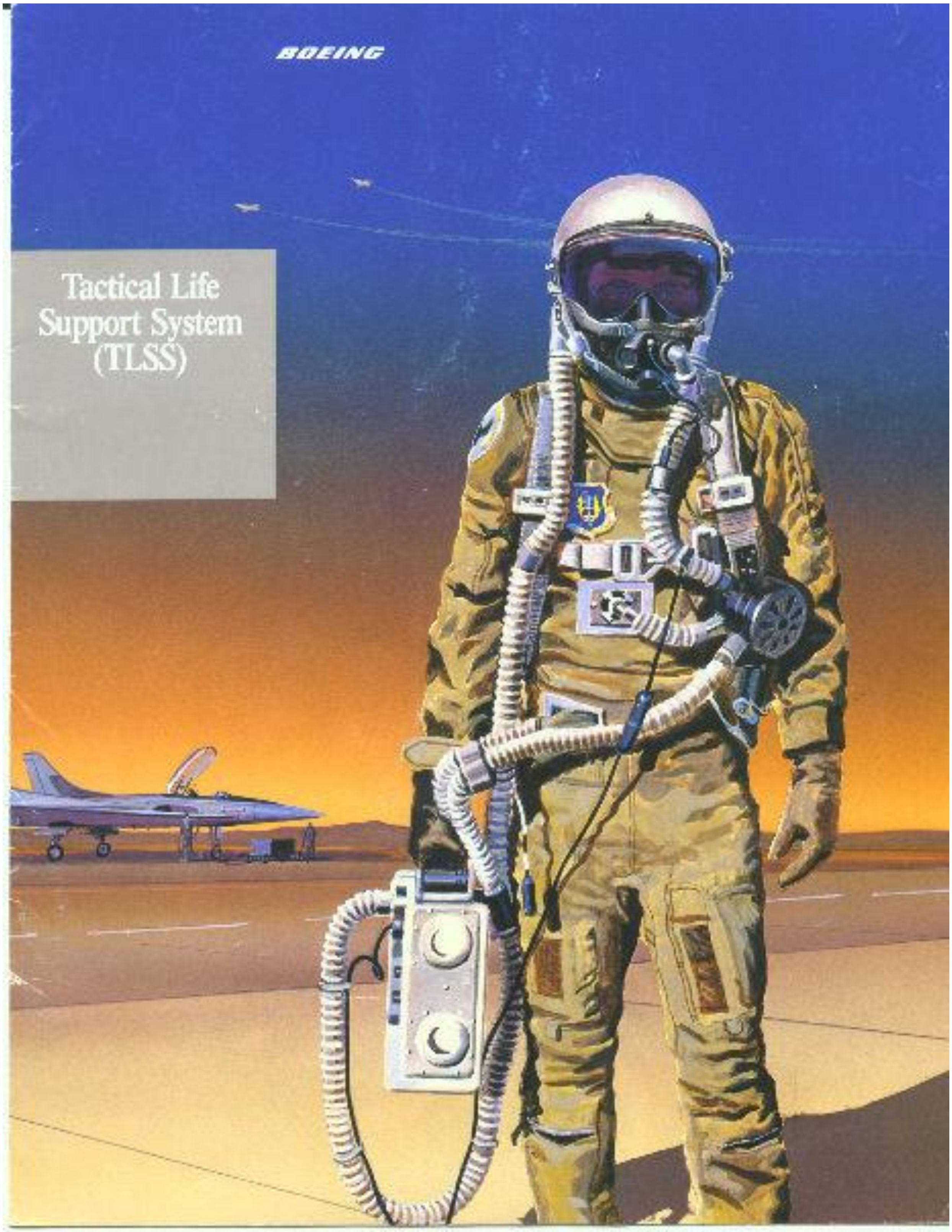
[Selected illustrations of the BOEING TLSS, GENTEX ICDS HGU-51/P, ATLSS (ACS), and Combat Edge (CE) assemblies appear on the following pages].

(Below: The full TLSS helmet/mask system, complete with full NBC and anti-flash goggles assy).

(Below: The full GENTEX ICDS HGU-51/P helmet/mask system; compare this system with the BOEING TLSS assembly, previously shown)

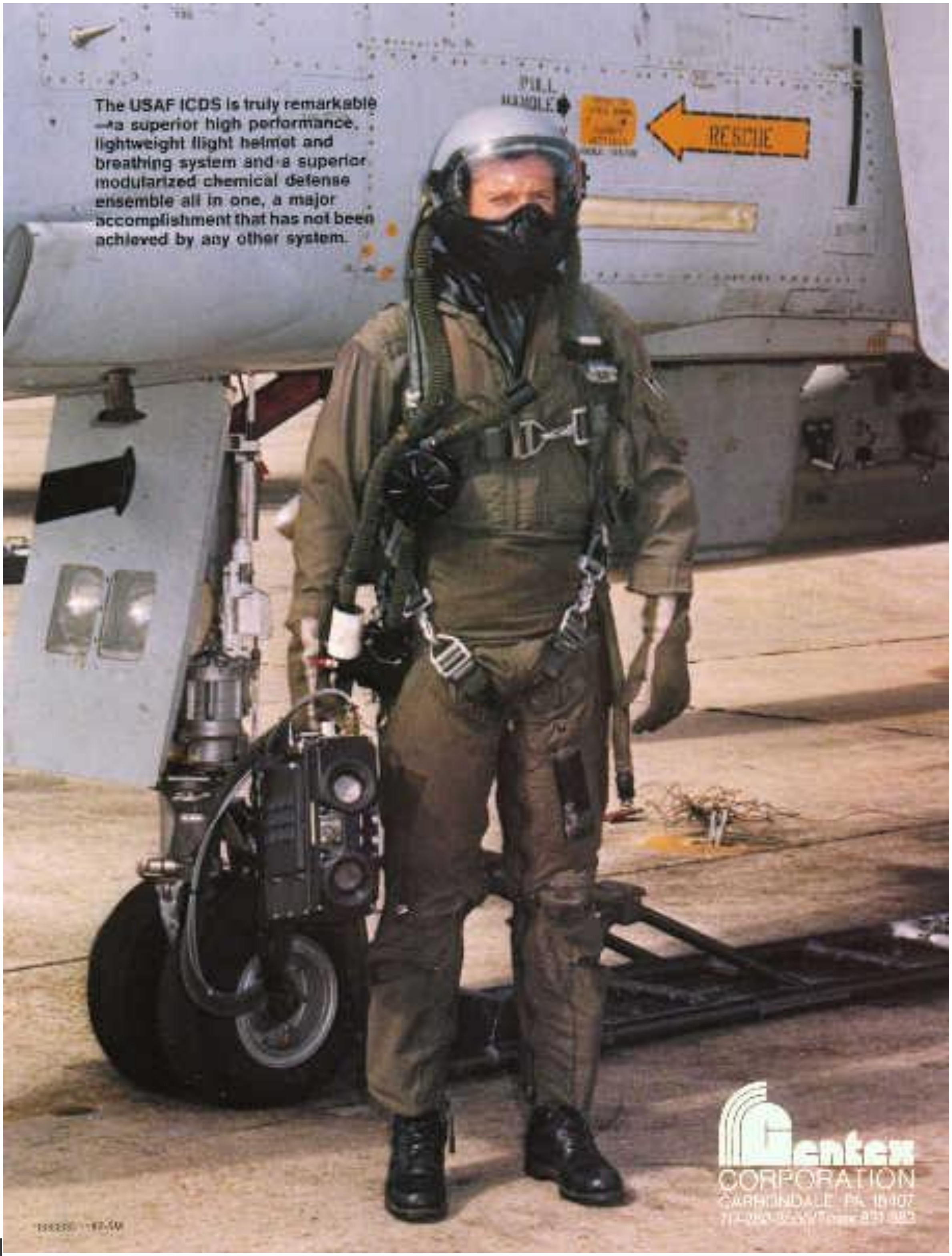
(Below: Early GENTEX Combat Edge Prototype: note oxygen mask hose configuration, based on TLSS system)

(Below: BOEING Aircraft Company TLSS promotional brochure, mid 80s)



(Below: The two primary TLSS suit/helmet assembly developmental variations, full suit & counter-pressure vest and lower cutaway pressure garment, much like conventional CSU-13/P 'speed jeans')

(Below: GENTEX ICDS assembly, with HGU-51/P system helmet component)



(Below: GENTEX ATLSS or ‘Advanced Tactical Life Support System’ prototype)

(Below: Production GENTEX ATLSS, also known as the Air Combat System, selectively used in certain NATO air forces, but not adopted by the US Air Force)

(Below: US Air Force Combat Edge or CE Assembly, ultimately derived adaptation of TLSS program)

(Below: GENTEX illustration of current production Combat Edge Assembly helmet/mask)

(Below: left side view of TLSS assembly helmet with NBC components attached—'non Fighter mode')

(Below: Two views of TLSS mask; note similarities to CE and ICDS systems)

(Below: Two views of the TLSS assembly in 'Fighter,' or non-NBC configuration)