# SOLUTIONS THAT PERMIT SAFER FLIGHT IN DEGRADED VISUAL ENVIRONMENTS (DVE)*

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*Recent combat experience in Operation Enduring Freedom and Iraqi Freedom has once again demonstrated the unforgiving nature of the desert environment. The total loss of aircraft, and near losses resulting in major damage, from a unique helicopter condition called „brownout" is disproportional to actual combat losses. Fully operational aircraft are routinely destroyed due to the loss of visual reference resulting from brownouts. This phenomenon is not new to rotary wing aviation but has now become a focal point of aviation commands as a problem to be solved. This paper puts forth several potential solutions that challenge our industry to provide a comprehensive answer to an urgent problem. The paper will address steps we can take now and in the future to improve a pilot's situational awareness and reduce the risk encountered during brownout events. Near term solutions represent more easily retrofitable elements that do not require a large amount of aircraft integration. These include sensor and display updates and modernized control laws. In the longer term advantage can be taken of the greater control authority afforded by Fly-By-Wire systems and further improvements in sensor technology.*

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## THE PROBLEM

Helicopters are routinely called upon to land at remote sites without the aid of navigation guidance. This is an every day occurrence in military desert and EMS operations. Basic aircraft control in these situations is dependant on visual cues. If the surface condition is such that dust, snow, sand, etc. are blown up by rotor downwash, the helicopter can be suddenly engulfed in a cloud of visually-restrictive material causing the pilot to lose contact with the ground and lose situational awareness. This condition is referred to as brownout or whiteout and can cause loss of aircraft control and failure to complete the intended mission. In addition DVE conditions are caused by haze, and severe IMC conditions. To recover, the pilot must convert to an instrument control technique, but generally there are no instruments to indicate what is needed to control the aircraft and continue the mission to landing or go around.

According to U.S. Army Flightfax, brownouts or whiteouts accounted for 24% of FY02 Class A accidents. A quote from a Flightfax describes the brownout problem as follows:

> While accidents caused by BROWNOUT are not the biggest problem aviators face you can count on there being at least two Class A or B accidents every year and that does not count Class C, D, and E that result from encounters with blowing dust. This is not just the new guys - the ones not long out of flight school and on their first tactical assignment that find themselves suddenly engulfed in blowing dust or sand. When this happens the crew loses sight of the ground, even someone with hundreds of flight hours can allow the aircraft to drift into the nearest obstacle or descend until the aircraft strikes the ground.

During operations in Desert Storm, Afghanistan and Iraqi Freedom the military helicopter community has seen an increase in brownout occurrences that are occurring on a continuing basis as a result of operating tactically in a desert environment.

***Fig. 1. U.S.Army 101st Airborne division soldiers walk near dust caused by a helicopter during a training course near Mosul, 400 kms (250 miles) north of Baghdad, Iraq, Thursday, Sept. 25, 2003. (AP Photo/Misha Japaridze)***

## THE SOLUTION

The ultimate solution to brownout and obstacle avoidance includes the integration of new and existing sensor technologies, the deployment of intuitive cockpit displays and the application of advanced flight controls that improve handling qualities and provide the pilot with the correct response type. This paper will address steps we can take now and in the future to improve a pilot's situational awareness and reduce the risk encountered during brownout events. Specifically, there are three areas of technology integration that could benefit the pilot in dealing with brownout:

1. Displays – Provide aircraft state information adequate to control the aircraft at low speed without visual reference to the ground.
2. Sensors – Provide outside scene information to „see through" the brownout, the ability to detect obstacles including wires/cables and to choose the flight path for a successful landing.
3. Flight Controls – Augment aircraft stability and control so that constant reference to visual cues is not required to maintain the basic control and flight path.

The technology exists today to enable brownout and whiteout helicopter operations under day or night all-weather conditions avoiding obstacles. The approach to be employed by Sikorsky includes the integration of these technologies to provide a total systems approach. It includes, first, an understanding of the flight path elements that make up approach, transition to hover and landing and the control strategy and visual cues used by a pilot to affect a safe landing. Next is developing a clear understanding of what the brownout/whiteout condition does to impair the visual cues with the resultant increase in the probability of an unsafe landing. The solution then applies improvements to the lost situational awareness using fused data from several sensor sources, intuitive 3D cockpit displays and improvements to the flight control systems to simplify the piloting task to minimize pilot error and provide an easily managed control strategy to the ground.

## NEAR TERM SOLUTIONS

The near term solutions are intended to address the helicopters flying today that are encountering brownout conditions. Some of these solutions represent more easily retrofitable elements that do not require a large amount of aircraft integration. This approach involves the incorporation of a well-designed, human factored hover 2D display with velocity cueing and acceleration cueing using GPS augmented Doppler or GPS/inertial velocity and position sensors with improved update rates and signal fidelity. The INS/GPS sensor proves to be a more capable sensor than the Doppler, which in the past has suffered from signal transit latency and update rate issues.

The incorporation of a new generation uncooled mobolometer FLIR camera with an appropriate display (See Fig. 2) will greatly improve a pilots' situational awareness at the final landing phase in brownout conditions because of its multi-element staring array and longer wavelength which can see more effectively through sand and dust obscuration than past FLIRS that had less photon receptors.

The new glass cockpit for the UH-60M has a new PFD-Hover and Attitude display. The Primary Flight Display over sub-mode provides a full compass rose with a navigation data display consisting primarily of a graphic and numerical representation of the hover mark point and of the aircraft velocity/acceleration. It is possible to incorporate a MAX-VIZ EVS-1000-3S type sensor video on the UH-60M PFD hover display as illustrated in the Fig. 2. The sensor is mounted on the tail underside of the aircraft looking forward into the „cone of silence" area directly under the aircraft that has the least amount of obscuration due to the down wash and outward flow of the rotor. This proposed hover display takes the normal ADI and replaces it with the enhanced vision information looking forward under the aircraft, which enhances the velocity cues of the hover display with actual visuals. While it is preferred to integrate this video stream into the HUD or primary displays in the long term, a quick, near term solution is to incorporate into existing HDD displays in the cockpit. This information, together with the hover display discussed above, should greatly increase a pilot's situational awareness in brownout conditions.

Obstacles, including wires and cables, can be detected with an imaging laser radar, generating images of the scene in front of the helicopter while real-time ranged data processing is performed in the integrated processing unit and displayed on the pilots displays. It is possible to detect wires that are approximately 5 mm in diameter from a distance of 750 m in good visibility conditions (12 km) and thicker wires from greater distances. An example of such a system is the Dornier HELLAS, which is now operating with the German Border Guard helicopters. The system has been evaluated on the US Army AATD BLACK HAWK and a German Air Force CH-53G and a newer military version is currently being evaluated by the US Army (Figs. 3 & 4). The integration and data fusion of such a system with a Control Flight into Terrain (CFIT) database and other sensors will not only allow prediction but detection.

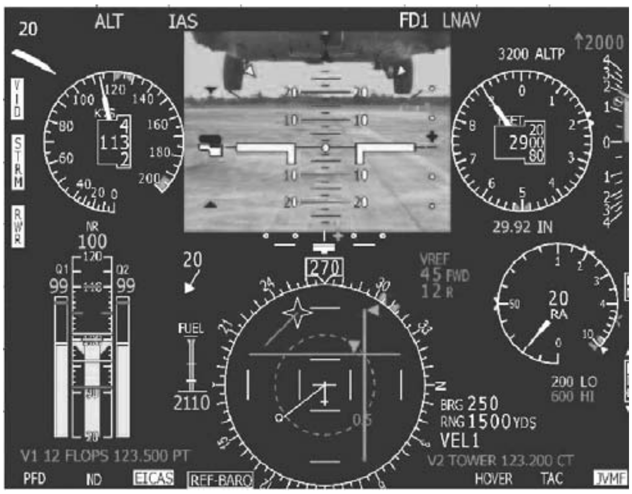


*Fig. 2. UH-60M PFD Modified with FLIR Landing Zone Video*


*Fig. 3. Safety line using the HELLAS LADAR*

*Fig. 4. Tree Obstacle Safety Warning using the HELLAS LADAR*

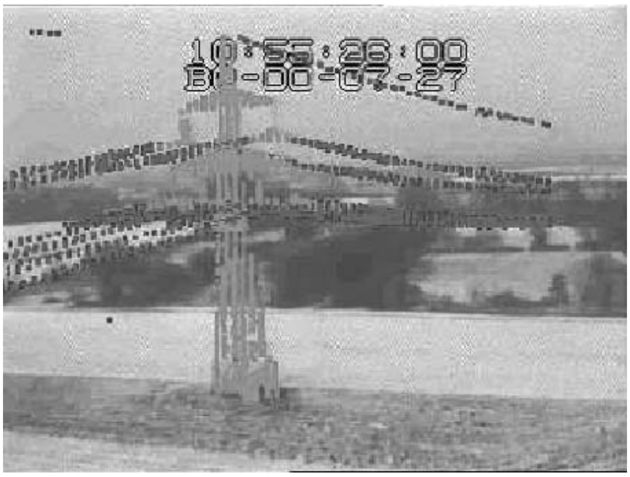

*Fig. 5. Wire Detection using the HELLAS LADAR*

Other obstacle warning systems include the Canadian 35 GHz Oasys scanning beam radar system that provides an audio and visual warnings for obstacles and wires based on safe detection and warning to the pilots based on aircraft position and closure speed. BAE and Sierra Nevada are currently developing radar systems in the 94 GHz band. The BAE FMCW (Frequency Modulating Continuous Wave) imaging system radar is now undergoing testing, and the results look very promising.

Modernized Control Laws (MCLAWS) provide a near-term control law solution by implementing the basic response type that is desirable in a brown out condition. These control laws have been recently flight-tested in BLACK HAWK with 10% authority SAS (which implies a dual-digital flight control computer). The flight-testing showed that the low-speed Attitude Command Attitude Hold (ACAH) response type implemented by MCLAWS improved all low-speed handling qualities to Level 1 and greatly reduced pilot workload (Ref. 2). Such a response type, which is also recommended by ADS-33E (Ref. 1) for DVE conditions, will go a long way towards improving safety in brownouts and other low visibility conditions.

In addition to the basic response type improvements, coupled modes of the type implemented on the UH-60M can be used to enhance safety in DVE. On the UH-60M, position hover hold allows the pilot to maintain position over a particular point on the ground. From position hover hold the pilot can "beep" aircraft position in 2 ft increments via a cyclic trim beeper. It is also possible to transition to velocity hold by holding the beeper in a desired direction for more than 2 seconds. Once in velocity hold the annunciations change and the velocity reference becomes visible on the hover display page. At this point it is possible to set velocity references to a desired value by using the trim beeper. It is also possible to depress trim release and hand-fly the aircraft to a desired velocity (in both lateral and longitudinal directions). Once at the desired velocity, release the trim release button and the aircraft will maintain present velocity. Position/Velocity hover hold modes also help manage a brownout condition. Once below 50 kts of airspeed, a pilot can depress cyclic beeper in, engaging the hover deceleration mode. In this mode, the aircraft maintains the radar altitude that was captured at time of engagement and decelerates the aircraft into a hover. Once hover is achieved, the aircraft goes into position hover hold mode, while still maintaining originally captured radar altitude.

## LONGER TERM SOLUTIONS: ADVANCED FLIGHT CONTROL SYSTEMS

The use of Advanced Control Laws, and the handling qualities improvements that follow, will help the pilot perform the approach and landing more safely when he encounters „brownout", through features such as altitude and hover hold, and approach and hover couplers. If visual references are lost, the pilot can choose to let the system „fly" the aircraft to a stable hover, rather than try to arrest the velocities through manual control. Additionally, once in a stabilized hover, beeper switches could be used to beep velocities or positions. A well-integrated combination of these features will support more precise and safe operations close to terrain. All of these features are available to different degrees on a range of products, but there is a need to integrate them together into a single comprehensive solution.

With the full authority FBW Flight Control System configured with Advanced Control Laws, the pilot can comfortably make predictable and precise changes to the flight path and have assurance that the helicopter will be tightly stabilized on the flight path (Ref. 3). Flight path disturbances due to gusts will also not saturate the control system that is trying to compensate, as possible with limited SAS authority stabilization systems. At very low speeds (less than 10 knots) such as is the case when in brownouts, the FBW Advanced Control Laws provide a linear ground velocity command mode which allows the pilot to control his speed over the ground directly, stabilizing to zero speed when not commanding an input. A hover capture control feature is available, which, when engaged, will arrest the aircraft velocities to zero speed and a GPS position hold will stabilize the hover point. Once in a stabilized hover, the piloting task of placing the aircraft on the ground, assuming that the landing site is receptive, will be an uncoupled vertical axis task, made even easier with the very low sensitivity control shaping afforded using digital FBW control algorithms.

## FUTURE

The vision for the future is to integrate additional sensors and cognitive displays into the aircraft to address enhanced obstacle avoidance in addition to brownout. Sensor technologies such as Ultra Wide Band (UWB) and Laser Radar (LADAR) have been shown effective at „seeing" wires and other potential obstacles in the flight path. Fusion of this sensor data using artificial intelligence that employs neuro-fuzzy estimators, B-spline networks and Bayesian techniques will allow an accurate image of the landing area together with terrain characteristics and obstacles; the resultant information when displayed in a isometric 3D image with FLIR or video will provide increasingly sophisticated situational awareness to the pilot and support see and avoid piloting. Advanced display formats can take maximum advantage of modern digital map/virtual terrain technology, velocity/ position sensing, synthetic vision and altimeter technology. The advanced display formats should allow the pilot to „sense" the velocities and 'see' nearby obstacles. Although heads up displays will likely emerge as the preferred visual aid, heads down displays will continue to predominate in the near future.

In the conceptual image in Fig. 6, a linear grid is overlaid on the 3-D digital map image. The grid spacing is selected to allow the pilots to perceive translation over the 3-D terrain. Lower altitudes result in a change in the visual spacing of the grid, and any obstacles detected by the on-board sensors are depicted as primitive „posts" on the grid/terrain image. An obstacle warning system safety line is also shown.

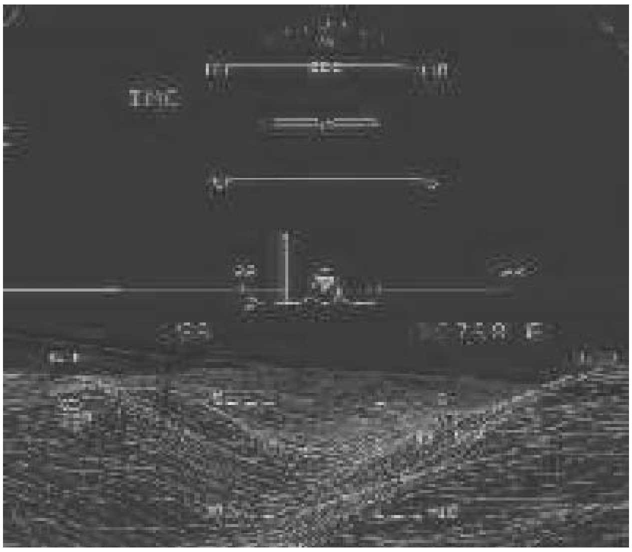

***Fig. 6. Enhanced Terrain Display showing Obstacle Clearance Safety Line***


## SUMMARY

The paper provides a discussion of technologies that are available today and those that will be available in the future for application to the brownout problem. These technologies fall into the categories of improved sensors, improved displays, and improved control laws. With a coordinated systems engineering approach, these disparate technologies can be effectively combined to provide solutions that will vastly improve helicopter operations in degraded visual environments.


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### ROZWIĄZANIA UMOŻLIWIAJACE BEZPIECZNIEJSZE LOTY W ŚRODOWISKU O OGRANICZONEJ WIDOCZNOŚCI


Streszczenie

Ostatnie doświadczenia wyniesione z Operacji Umacniania Wolności i Wolność Irakowi jeszcze raz podkreśliły surowość środowiska pustynnego. Całkowite straty statków powietrznych i bliskie całkowitej utracie poważne uszkodzenia zdolności operacyjnej śmigłowców wskutek zaniku widoczności są nieporównywalnie duże w stosunku do całkowitych strat w boju. Statki powietrzne będące w całkowitej zdolności operacyjnej bywają systematycznie uszkadzane wskutek utraty wizualnego źródła danych na skutek spadku widoczności. Owo zjawisko nie jest niczym nowym dla wiropłatów, lecz obecnie stało się obiektem zainteresowania dowódców lotnictwa, jako problem do rozwiązania. W artykule przedstawiono kilka potencjalnych rozwiązań stanowiących wyzwanie dla naszego przemysłu, przedsięwzięć kompleksowych działań celem odpowiedzi na nurtujący problem. Pokazano poszczególne kroki, jakie możemy podjąć teraz i w przyszłości, aby poprawić możliwość orientowania się w sytuacji przez pilota oraz zmniejszyć ryzyko w trakcie zaników widoczności. Jako rozwiązania proponuje się wymianę elementów na nowe, które nie wymagają skomplikowanej integracji z systemami płatowca. Rozwiązania również obejmują aktualizację czujników, wyświetlaczy i modernizacji charakterystyk sterowania. W dalszej perspektywie czasowej można odnieść korzyści ze zwiększenia znaczenia elektronicznego układu sztucznej stateczności i sterowania oraz dalszych udoskonaleń czujników.

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## РЕШЕНИЯ КОТОРЫЕ ПОВЫШАЮТ БЕЗОПАСНОСТЬ ПОЛЁТОВ В УСЛОВИЯХ ОГРАНИЧЕННОЙ ВИДИМОСТИ (DVE)

Резюме

Последний военный опыт приобретённый во время операций Укрепить Свободу и Свобода Для Ирака ещё раз показал как сурова натура пустынных условий. Потери связанные с полным разбитием или тяжёлым поврждением вертолётов вызванных условиями потери видимости (анг. браунаут) оказались непропорционально большими по сравнении с потерями в борьбе. Вертолёты в полной готовности часто разбиваются по причине потери видимости. Это не новое явление для вертолётной авиации но теперь для авиакомандования решить эту проблему стало одной из важнейших задач. В статье показано несколько потенциальных решений которые бросают вызов нашей промышленности чтобы предприняла комплексные действия для решения этой проблемы. Показаны действия которые можно предпринять теперь и в будущем чтобы улучшить оценку ситуации пилотом и снизить риск если произойдёт браунаут. Решения которые можно ввести быстро это применение новых элементов которые не нуждаются в большой работе по их интеграции с вертолётом. К ним относятся новые датчики и табло и модернизация систему управления. В дальнейшем времени корысти может принести применение новой системы управления полётом с вспомагательными системами Fly-By-Wire и дальнейшими улучшениями в технологии датчиков.