Assessment of Brownout Mishaps in Military Rotorcraft

Joshua A. Schwartz and William L. Greer

The value of the 26 destroyed rotorcraft between 2000 and 2013 due to brownout was approximately $533 million based on military cost documentation. About half of these aircraft losses and three-fourths of the costs were borne by Army helicopters.

A degraded visual environment called a brownout occurs when dust, sand, and debris envelop rotorcraft operating close to the ground and aircrews experience spatial disorientation and loss of situational awareness. Collision, crash landing, or dynamic rollover of the affected rotorcraft can result. In 2014, in response to brownout-induced mishaps that occurred during Operation Iraqi Freedom in Iraq and Operation Enduring Freedom in Afghanistan, the U.S. Army conducted an analysis of alternatives for the Brownout Rotorcraft Enhancement System (BORES). To inform the Army's analysis, IDA estimated the costs of future losses of the Army's H–47 and H–60 helicopters based on costs of all U.S. military rotorcraft mishaps for 2000–2013. The overall investment in BORES versus the savings that could be realized by avoiding helicopter losses was one metric the Army used to assess the value of BORES. This article explains the method used to estimate the costs of potential future losses.

Background

Rotorcraft such as helicopters and vertical takeoff and landing aircraft create what is known as downwash, which is the force of air equal to and in the opposite direction of the force the aircraft exerts on the rotor to produce lift. For rotorcraft operating close to the ground over arid desert terrain, downwash can cause dust, sand, and other debris to circulate upwards and envelop the rotorcraft. The resulting degraded visual environment is called a brownout.

Rotorcraft landings and near-ground hovers are particularly vulnerable to brownouts (Figure 1). The rotorcraft's aircrew can experience spatial disorientation and loss of situational awareness, resulting in collision with an obstacle, crash landing, or dynamic rollover.

Approach

Aircraft mishaps are grouped into discrete classes based on a combination of property loss and personnel casualty levels involved. Those involving the highest costs or loss of life are Class A mishaps, which is our focus here. These involve one or more of the following: total rotorcraft loss through destruction, total cost of damages in excess of $2 million, or one fatality or

Figure 1. Military Helicopter Brownout

permanent total disability. Class B mishaps are the next most costly and serious mishaps, and Class C and D mishaps are progressively less costly and less serious.

Historical Mishaps

An IDA research team investigated rotorcraft mishaps occurring between 2000 and 2013, a period including many brownout incidents in both Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF). By direction from the Army, we focused only on brownout-induced mishaps and not those caused by other degraded visual environments such as snow, rain, smoke, darkness, fog, smog, flat light, or clouds. Previously published literature (e.g., U.S. Army Program Executive Office, Aviation [2011]) was ambiguous about the numbers of degraded visual environment mishaps caused solely by brownout, so we set out to clarify those distinctions.

We used records maintained by the U.S. Army, Air Force, and Navy Safety Centers. Brownout mishaps were organized into categories that included the extent of property damage, fatalities and injuries, year, location (OIF/OEF or Rest of World [ROW]), branch of the military, aircraft type and model, day or night conditions, and flight phases. Flight-hour data were then used to calculate the average numbers of brownout-induced incidents per 100,000 flight hours, which is the standard rate metric within the aviation safety community. This rate was crucial to projecting future mishaps. We also estimated costs associated with these losses.

Future Mishaps

Next, we examined the possibility of avoiding future brownout mishaps for the Army H–47 and H–60 rotorcraft, the two helicopters in the U.S. Army's BORES analysis of alternatives. Using future inventory projections, we estimated the number of future mishaps that would occur without BORES. Flight-hour assumptions were bracketed by two operational tempos: programmed flight hours and the higher numbers of flight hours experienced in fiscal years (FYs) 2000–2013. The flight-hour environments were also bracketed by ROW exclusively and a combination of ROW plus OIF/OEF.

We also estimated costs for the projected numbers of rotorcraft lost or subject to Class A repairs. Using inflation indices, we calculated all costs in FY 2014 dollars. From this, we determined the approximate break-even cost, defined as the dollar amount where the full unit life-cycle cost of implementing BORES on these aircraft equals the estimated cost of the mishaps prevented.

Selected Findings

Historical Mishaps

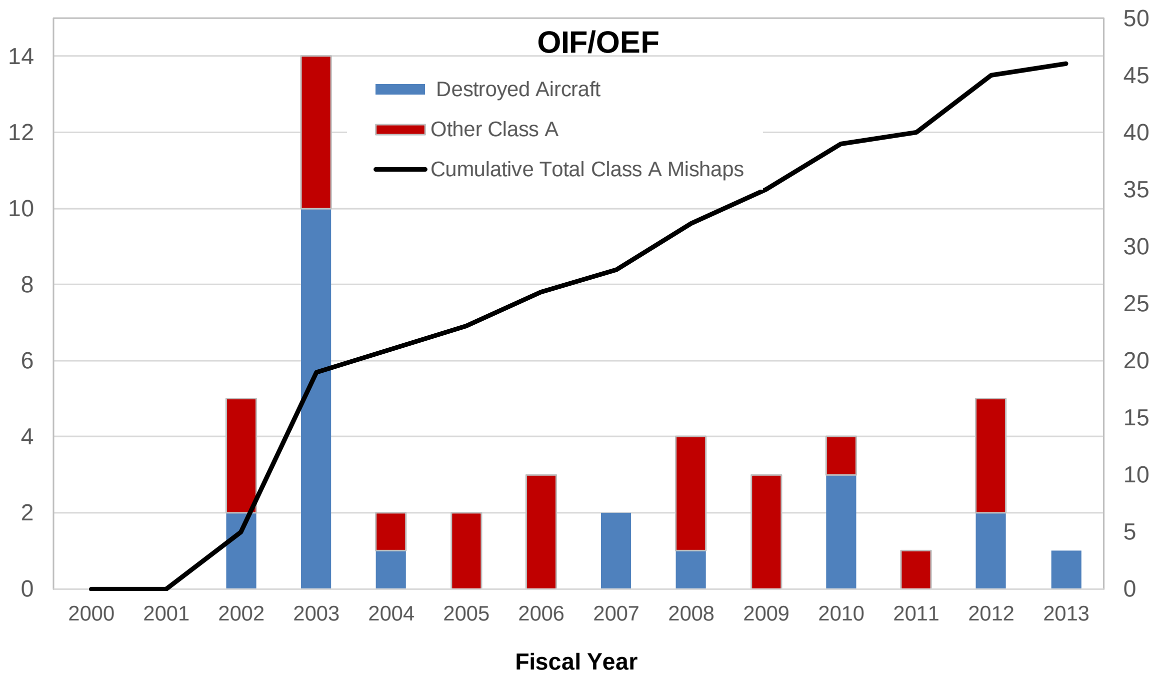
The numbers of Class A mishaps attributed to brownouts from 2000 through 2013 are provided in Figure 2. All branches of the U.S. military are included. The stacked bars use the scale on the left and comprise lost aircraft and other (repairable) Class A incidents. The cumulative total numbers of Class A mishaps are also displayed with the overlaid lines using the scale on the right. A spike in mishaps during the initial OIF/OEF operational buildup is clearly shown. For the ROW, by comparison, relatively few brownout mishaps occurred over the same period and, in many years, none at all. Overall, 26 rotorcraft losses occurred among the 53 Class A brownout mishaps recorded between 2000 and 2013. Of these 26 losses, OIF/OEF accounted for 22 of them.

Over two-thirds of the brownout-induced Class A mishaps involved Army helicopters—virtually all in OIF/OEF, as shown in Figure 3 (OIF/OEF on the left bar chart, and the ROW on the right bar chart). The table below each bar chart shows the types of rotorcraft involved. Within each cell, the first number is the number of aircraft destroyed; the second is the number of other Class A mishaps.

Brownout is not the only cause for rotorcraft mishaps. Military records show that of all rotorcraft lost in OIF/OEF between 2000 and 2013, only 17 percent are attributable to brownout. For the ROW, the brownout Class A mishaps represent fewer than 4 percent of all other mishap causes. The total number of Class A brownout mishaps in OIF/OEF and the ROW combined account for about 12 percent of all mishap events.

These brownout mishaps resulted in 6 fatalities (all in OIF/OEF) and 175 injuries (147 in OIF/OEF) across all branches of the military. Of these, U.S. Army rotorcraft were involved in 3 fatalities (all in OIF/OEF) and 107 injuries (88 in OIF/OEF).

The value of the 26 destroyed rotorcraft between 2000 and 2013 due to brownout was approximately



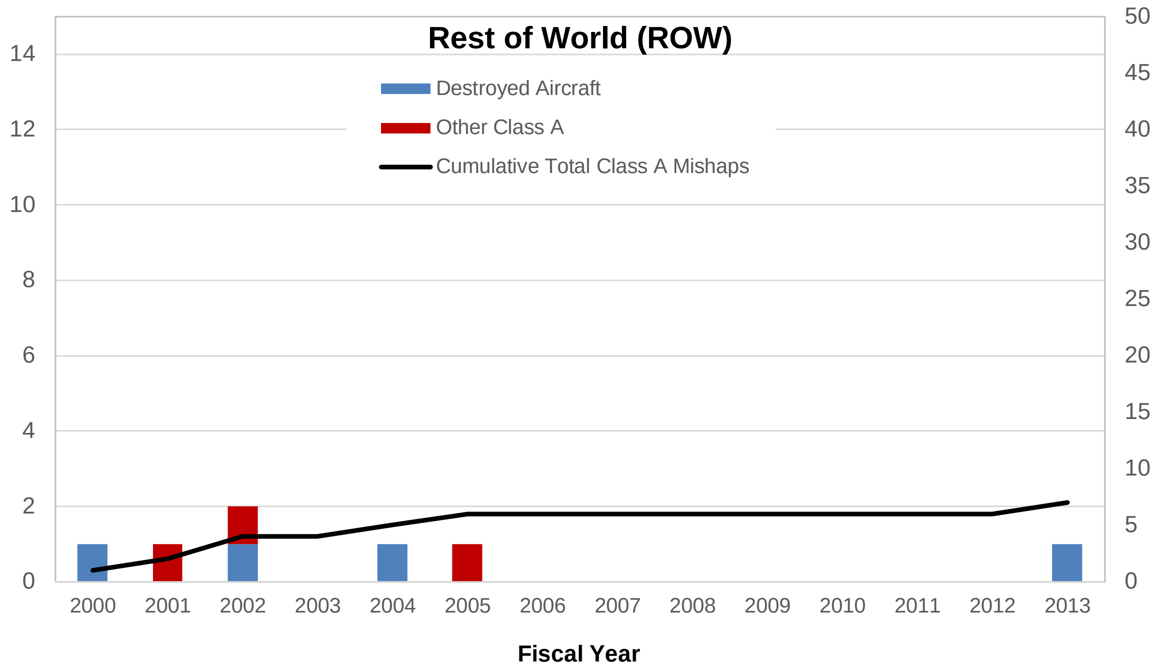
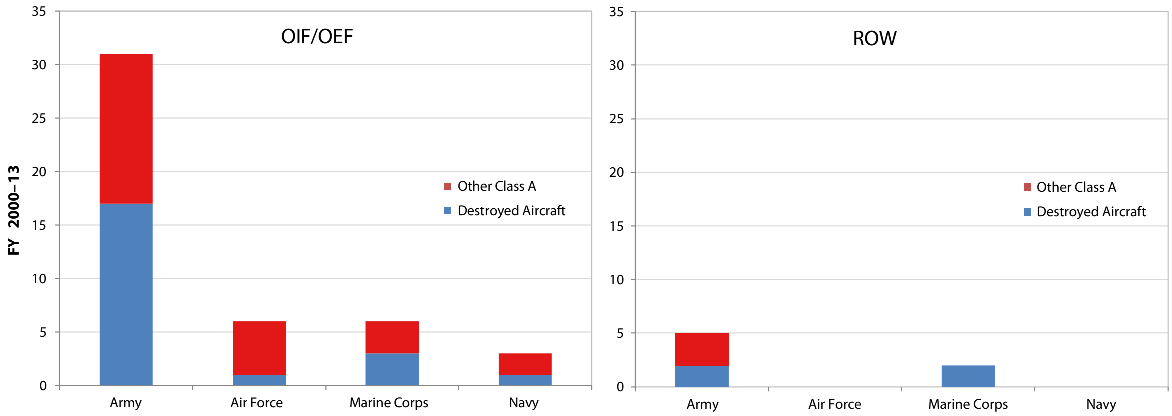


Figure 2. Class A Brownout Summary for OIF/OEF (Top) and ROW (Bottom): All Military Branches by Year



# Destroyed Aircraft + # Other Class A				
Rotorcraft Type	Army	Air Force	Marine Corps	Navy
H–60	2 + 11	0 + 5	0	1 + 2
H–47	7 + 3	0	0	0
H–58	4 + 0	0	0	0
H–64	4 + 0	0	0	0
H–1	0	0	2 + 1	0
H–53	0	1 + 0	1 + 2	0
H–46	0	0	0	0
Total	17 + 14	1 + 5	3 + 3	1 + 2

# Destroyed Aircraft + # Other Class A				
Rotorcraft Type	Army	Air Force	Marine Corps	Navy
H–60	2 + 2	0	0	0
H–47	0	0	0	0
H–58	0 + 1	0	0	0
H–64	0	0	0	0
H–1	0	0	1 + 0	0
H–53	0	0	1 + 0	0
H–46	0	0	0	0
Total	2 + 3	0	2 + 0	0

Note: Figures in red were the focus of our research—Army H–60 and H–47 Class A mishaps.

Figure 3. Total by Military Branch and Rotorcraft Type

$533 million based on military cost documentation. About half of these aircraft losses and three-fourths of the costs were borne by Army helicopters.

Future Mishaps

To estimate the numbers and types of future incidents in the absence of BORES, the researchers combined flight hours, inventories, and mishap rates.

Flight Hours

Between 2000 and 2013, records show that the average number of flight hours per aircraft per year was 224 for the Army's H–60 and 181 for its H–47. By contrast, the programmed flight hours per aircraft is lower: 163 for the H–60 and 128 for the H–47. Therefore, two bounding cases for annual flight-hour rates were considered: a lower bound using programmed values and an upper bound using the more demanding FY 2000–2013 experience.

Inventories

The inventory projections for the H–60 and H–47 through the end of their service lives are shown in Figure 4, which indicates that essentially all H–47s and H–60s will be retired by 2050. Figure 5 shows the number of remaining flight hours each year based on the inventory projections and under the two flight-hour bounding assumptions.

Mishap Rates

Average Class A brownout mishap rates based on historical analyses for the Army H–60 and H–47 combined are displayed in Table 1.

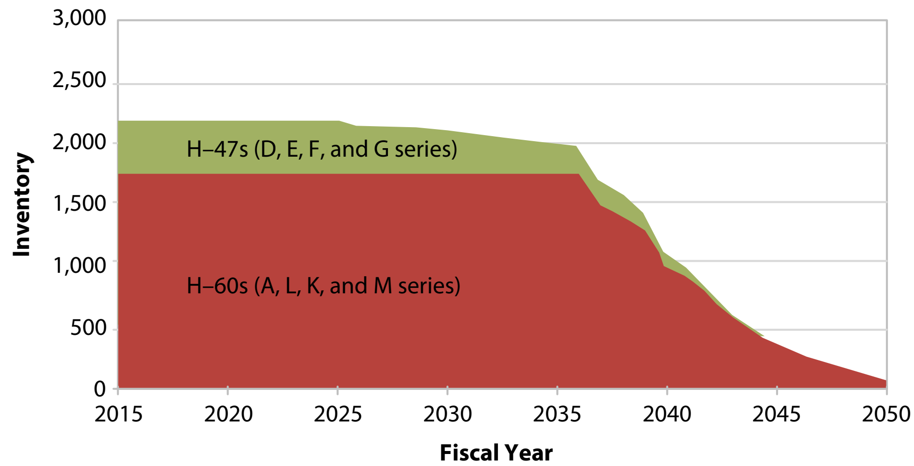


Figure 4. Projected Inventories of Army H–47 and H–60 Helicopters through 2050

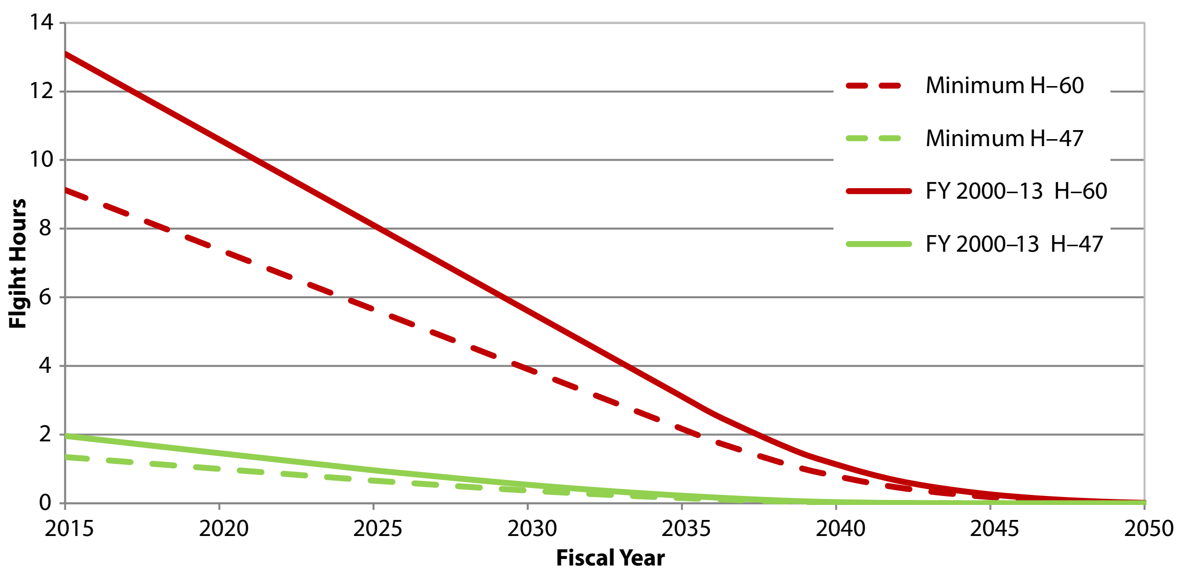


Figure 5. Remaining Flight Hours for Army H–47 and H–60 Helicopters through 2050

Table 1. Brownout Class A and Destroyed Rates, 2000–2013

Location (Category)	Selected Parameter for 2000–13 Timeframe	H–60 + H–47 Combined Value
OIF/OEF	Class A Brownout Rate Loss from Brownout Rate	0.89 0.35
ROW	Class A Brownout Rate Loss from Brownout Rate	0.11 0.06

Note: All rates represent numbers of mishaps per 100,000 flight hours.

Costs

The Class A brownout mishap costs included rotorcraft losses as well as repairs. Mishap costs were based on the value at the time the mishap occurred, so they were time dependent. Army cost data were used for the H–47 and H–60 rotorcraft acquisition and modifications, the aircraft were given diminishing value over a 35-year period as they aged, and all costs were reported in FY 2014 dollars no matter when the mishaps were expected to take place. The mishap costs did not include casualties because the casualty rates from OIF/OEF and ROW experiences were low and official indemnity estimates are varied and undetermined.[1]

Cases

The baseline case is a hypothetical one for comparison in which BORES is implemented in a single year (2015) for the entire fleet of approximately 2,669 rotorcraft (534 H–47s and 2,135 H–60s). More realistic cases would implement BORES on only a portion of the fleet each year and potentially not even on all fleet aircraft. Given this, we explored three cases that would begin introducing BORES in 2017:

- *Case 1:* BORES introduced into the full H–47 and H–60 fleet to include installation in new-build/remanufactured aircraft as they are delivered and retrofits on existing H–47s and H–60s at a rate of 200 per year.
- *Case 2:* BORES introduced for only one-third of the H–47 and H–60 fleet with the newest/most valuable aircraft covered and proportional effectiveness (one-third of projected losses prevented) at an installation rate of 200 per year. One-third represents approximately the total fleet fraction deployed to OIF/OEF during 2000–2013.
- *Case 3:* Same as Case 2, but with all projected losses prevented through judicious deployment to theater of only BORES-outfitted aircraft.

In Case 3, only the aircraft fitted with BORES would be deployed where brownout conditions might be encountered. In Case 2, aircraft are randomly used where needed, so only one-third would be properly protected against extreme brownout conditions.

Figure 6 shows the break-even unit life-cycle costs for the three cases mentioned above along with the hypothetical 2015 baseline case for comparison. Case 1 had lower break-even values than the baseline, since implementation would take place over a longer span of time, and fewer mishaps could be prevented within the remaining lifetime of the H–47s and H–60s. Case 2 had higher values because only the newer and more valuable aircraft would be affected. In Case 3, fewer aircraft would need to be upgraded to prevent all projected brownout losses, so its break-even value was the highest.

[1] The original IDA paper on which this article is based shows that the inclusion of casualty costs would increase total costs by less than 10 percent and, in some cases, by far less than 10 percent (Greer et al. 2014) for different government value systems.

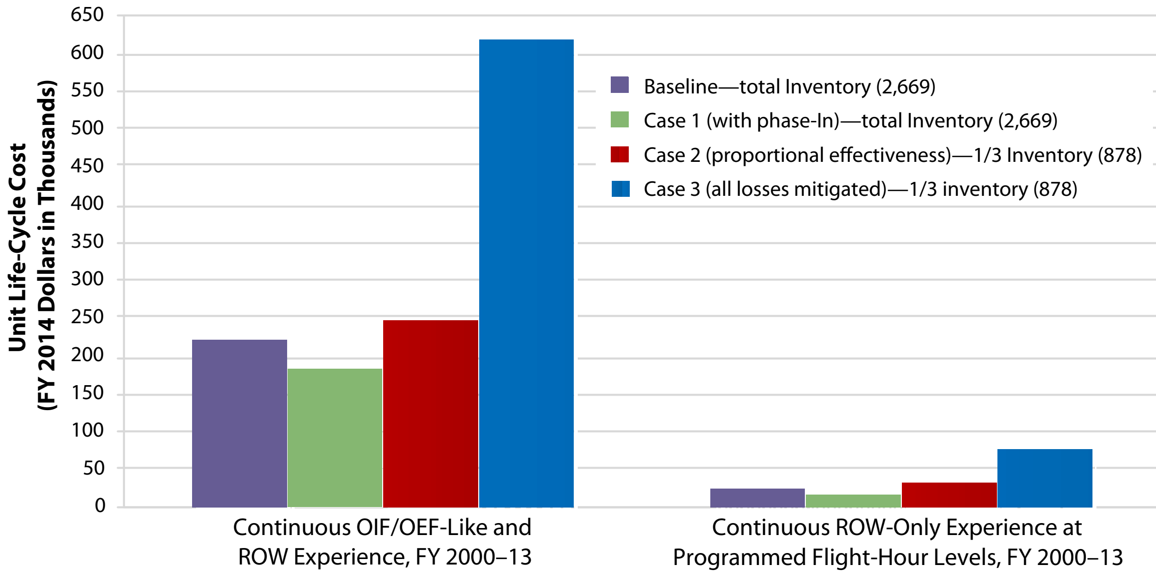


Figure 6. Break-Even Cost Excursions

Summary

Historical records of brownout-induced rotorcraft mishaps for all branches of the military were investigated from 2000 through 2013. An assessment of the cost of aircraft destroyed from brownout in the same 14-year period indicated a cost of around $533 million total in FY 2014 dollars from 26 losses. About half of the losses were Army rotorcraft.

We used these historical data to make projections of numbers and costs of future brownout Class A mishaps involving Army H–47 and H–60 rotorcraft. The costs were expressed in terms of break-even costs, the values at which the cost of BORES equaled the cost of rotorcraft saved. If BORES were introduced starting in FY 2017 for inclusion in new-build or remanufactured aircraft and as retrofits to existing H–47s and H–60s at a rate of 200 per year, a cost-effective BORES life-cycle cost for each of the cases examined should be as follows:

- *Case 1:* less than ~$30,000 per unit if 2000–2013 ROW-only environment prevails and programmed flight hours continue indefinitely (i.e., for lifetime of the fleet).
- *Case 2:* less than ~$245,000 per unit if only one-third of the fleet is outfitted with BORES and if the 2000–2013 operating situation (including more demanding OIF/OEF-like conditions plus ROW) prevails and continues indefinitely. Aircraft are randomly selected for deployments, so one-third would be protected in OIF/OEF-like brownout conditions.
- *Case 3:* ~$600,000 per unit if only one-third of the fleet is outfitted with BORES, and to minimize losses to brownouts, these are the only rotorcraft used in 2000–2013 OIF/OEF-like conditions indefinitely.

Clearly, BORES would prove most cost-effective when only a third of the fleet is outfitted with the new systems and then deployed selectively in OIF/OEF conditions to minimize brownout losses. This approach minimized the numbers of BORES units acquired while maximizing brownout mishap reduction. It is least cost-effective if ROW conditions with minimal brownout environments dominate the future.

Finally, although the focus for this analysis was brownout mishaps, brownouts accounted for only 12 percent of all Class A rotorcraft mishaps between 2000 and 2013. Extension of the analyses to include additional types of rotorcraft mishaps that could be mitigated by a BORES alternative might thereby raise the break-even cost values, making BORES a more attractive alternative. The Army has subsequently expanded its examination of technologies to encompass solutions to mitigate the wider problem of degraded visual environments.

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Joshua Schwartz (left), a Research Staff Member in the System Evaluation Division (SED) of IDA's Systems and Analyses Center, holds a master of science in aeronautical engineering from Rensselaer Polytechnic Institute.

William (Bill) Greer (right), an Assistant Division Director in SED, holds a doctorate in chemistry from the University of Chicago.

The full article nominated for the Welch Award was published in *AHS [American Helicopter Society] International 71st Annual Forum Proceedings*, May 5–7, 2015, Virginia Beach, Virginia. For details of the work IDA undertook with co-sponsorship from the Joint Chiefs of Staff, see IDA Paper P-5206, *Mishap Analysis for Brownout Rotorcraft Enhancement System (BORES) Analysis of Alternatives (AoA),*" W. L. Greer, A. O. Gallo, B. R. Harmon, B. C. Prindle, J. A. Schwartz, J. Silva, J. W. Stahl, and R. V. Uy.