2002 Crash of the Lockheed C-130 Hercules in Walker, California

STS Research Paper
Presented to the Faculty of the
School of Engineering and Applied Science
University of Virginia

By

Logan Patrick Honts

May 11, 2022

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

Signed: Logan Patrick Honts

Approved:
Benjamin Laugelli, Department of Engineering and Society

Introduction

Wildfires and bushfires are on the rise globally due to rising temperatures and fluctuating weather patterns. The fires' potential to cause damage and fatalities is only exacerbated by the inadequate response capacities of aerial firefighting units, both in the United States and worldwide (Mak, 2021). In order to adequately address the increasing danger of wildfires, firefighting aircraft responding to them must be reliable. They must not fail during service, and must be replaced and cycled out of service before they do. For this to happen, a network of maintenance operations must be established and upheld to ensure the safety of firefighting aircraft. With the Lockheed C-130 Hercules crash near Walker, California in 2002, however, this was not the case. Both wings separated from the C-130's fuselage while completing a drop of fire retardant, causing it to impact the ground and burn up, fatally injuring all three crew members.

Presently, firefighting aircraft used in the United States are, at best, older models of passenger or cargo aircraft modified for firefighting applications. However, these airframes are not meant to fly with large fluid payloads on board and have gained significant age since their first usage. A mismatch between the original design purpose of these aircraft and the necessary capabilities for aerial firefighting, such as maneuvers and slower flight speeds, has led to several crashes throughout recent history, as shown in Fig. 1 (Stonesifer et al., 2014), yet the original maintenance procedures continue to be used throughout aerial firefighting organizations. Misunderstanding that incompatible maintenance procedures could be sufficient to support the aerial firefighting network puts these pilots at risk. In order to better understand why this network failed, resulting in the crash of the C-130 Hercules, the nonhuman actors, organizational managers, and outside pressure on the network must all be accounted for. To demonstrate this, I will utilize Actor-Network Theory developed by Michel Callon to determine which actors decohered from the aerial firefighting network and contributed to the crash of the C-130 Hercules.

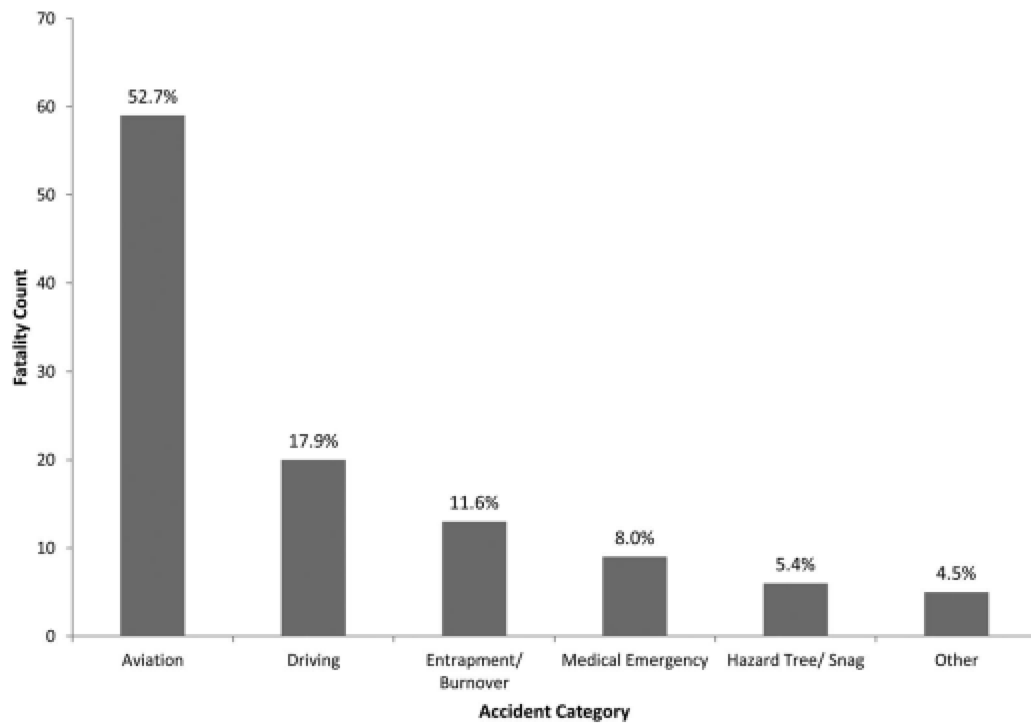

Fig. 1. Relative Frequencies of Accidents in Firefighting Operations from 2000-2012

I will deliver a better understanding of the social factors contributing to the crash through my analysis of the C-130 Hercules crash. This paper will offer insights on how a firefighting aircraft network should function to account for various groups of human and nonhuman actors and succeed at fighting wildfires in the real world. Through my analysis, I will contribute to the understanding of the network requirements needed to properly support all involved in aerial firefighting.

Background

At the time of the crash, it was determined that major cracks were present in the rivets fastening the wings to the fuselage, causing them to fold up during the pitch maneuver and subsequently detach. Fatigue loading caused these cracks to propagate from a very small size to over twelve inches long during the C-130's 21,863 hours of flight service. Following this crash and analysis, the United States Forest Service (USFS) and Bureau of Land Management (BLM) ordered an inspection program called the Blue Ribbon Panel to determine the airworthiness of the current fleet (West, 2004). This resulted in revoked contracts and grounding of the entire fleet due to safety concerns (Testimony, 2003). The inspection completed by National Transportation Safety Board (NTSB) after the incident concluded that "there was no specific inspection requirement for cracks in the fastener holes" (*NTSB accident summary for N130HP,* 2002, p. 14).

Literature Review

While the C-130 Hercules crash has been extensively analyzed since 2002 by the Blue Ribbon Panel and the NTSB, their focus was on finding probable causes of the crash from video evidence, maintenance records, and damage that could be observed in the wreckage. They did not, however, propose any fundamental, root causes for the crash due to the human network the aircraft and pilots operated in. This crash has not previously been analyzed by scholars in the field of aviation. Despite this lack of scholarly analysis, there has been related work written on other similar crashes outside of aerial firefighting for transport aircraft that is applicable to the analysis of the C-130 Hercules crash.

Alaska Airlines Flight 261

The first notable incident that is relevant is the crash of Alaska Airlines Flight 261 on January 31, 2000, analyzed by members of the Stevens Institute of Technology (Schnedler et al., 2007). In this crash, the National Transportation & Safety Board (NTSB) determined that a failure of the jackscrew assembly in the horizontal tail was the mechanical failure that caused the nose to pitch down beyond recovery, resulting in the crash. The maintenance crew was largely at fault due to inadequate job performance leading up to the crash, as it was discovered that the bolt holding the assembly in place had experienced 90% wear when it should have been replaced at only 22% wear. Members of the maintenance crew repeatedly signed off on incomplete work, used homemade measuring instruments to inspect wear on aircraft parts, and would measure repeatedly until the desired number, within tolerance, was measured. Not only were the maintenance crew negligent of their duties, but in the years leading up to the crash, intervals between maintenance checks were doubled due to poor federal-local cooperation over Federal Aviation Administration (FAA) regulations. If this weren't enough, a pervasive "culture creep" of lax adherence to Alaska Airlines' own regulations for inspection permeated the maintenance crew over time. Schnedler et al. argued that outside market pressure between 1990-2000 pushed the airline company to increase performance and number of planes operable per day, rather than taking the necessary time to perform equipment checks at the proper intervals. Alaska Airlines did seek help from the FAA by requesting more maintenance checks, but these manifested as increased time between checks rather than increased staff or funding. Alaska Airlines also felt pressure from the "onus" culture of the FAA and the manufacturers of the jackscrew assembly to take care of the issues that arose independently. The FAA even made this statement regarding determining whether the tools the inspection team used were accurate enough:

> [it] is the primary responsibility of the repair station or air carrier, not the FAA. …[the manufacturers of the jackscrew assembly did not solve] the problem because they did not recognize it as their problem. (p. 47)

This exemplifies the prevailing attitude at the time of shedding responsibility (and thus liability) once the initial job or certification has been completed. The members of the Stevens Institute of Technology found that due to these attitudes of complacency towards maintenance procedures and hands-off reactions to requests for help, the safety of the organization eroded over time, allowing this accident to occur.

Risk management in aerial firefighting organizations

Stonesifer et al. wrote more specifically about risk management and decision making in aerial firefighting operations. In this paper, they developed an Aviation Exposure Index (AEI) to correlate time in the air on a firefighting mission to the likelihood of an accident occurring in the field. They developed this to address the bad track record of accidents between 2000-2011 and this common, but concerning mindset:

> In a 2011 survey of Forest Service fire managers…, only 37% of respondents agreed with the statement, "[t]hrough operational risk mitigation, managers can eliminate risks of fatality to aviation personnel deployed on a wildland fire incident."

They also note inconsistent bookkeeping across agencies, and when responding to small fires, with mission logs and flight time often reported under miscellaneous codes for billing purposes. They also argued that local fire chiefs need to take into account the unique missions of aircraft dispatched to the wildfire location, as tasks can vary widely from dropping retardant to create a fire block, dousing an early fire with water to stop its spread, or general reconnaissance and supply drops for ground crew. These extended periods of operation with many heavy loadings occurring on the aircraft structure (compared to a standard transport aircraft) create a recipe for accelerated aircraft aging and increased risk per hour spent fighting a fire. Thus, Stonesifer et al. assert that using their AEI to inform decisions made by fire chiefs in the field is a must when it comes to safety in aerial firefighting.

These scholars each recognize that the lack of a standardized mode of operations upheld at all times can be common among both transport and firefighting airlines. Inaccurate reporting and pressure for the most return on aircraft investment leads to increased risk taking attitudes among organizational managers and a lapse in stringent maintenance over time, putting the pilots and passengers in danger. Where these scholars fall short is specifically applying that reasoning to the field of aerial firefighting. Firefighting aircraft are exposed to higher temperatures, loads, and flight times that cause them to age more rapidly and be more at risk for fatigue failure due to maintenance oversight. My analysis with Actor Network Theory below addresses these shortcomings by highlighting the importance and power that each individual actor within the aerial firefighting network has on the entire network's overall success.

Conceptual Framework

Actor Network Theory, developed by Michel Callon, Bruno Latour and John Law (Cressman, 2009), highlights how interconnected the various parties, or "actors," are to the success of an aerial firefighting operation, or "network," as illustrated in the Lockheed C-130 Hercules crash of 2002. Actor Network Theory involves a heterogeneous network of both human and nonhuman actors, assembled by a network builder, that sustains operations of a particular technology in society and solves a problem. The parts of this theory that are significant for this paper are what Callon calls "translation" - the task of forming and maintaining a network. This process consists of four main steps: problematization, interessement, enrolment, and mobilization (Callon, 1986). Problematization consists of a network builder that identifies the issues to solve and the actors necessary to recruit to realize their goal. During interessement, the network builder recruits human and non-human actors into the network in an effort to align their interests with the network's and ensure smooth operation. Once interessement is finished, enrolment begins and the actors recruited by the network builder are given their role within the network. Throughout the life of the network, the actors recruited in interessement must perform their assigned roles in enrolment, lest they become “rogue actors”, or actors that stop fulfilling their purpose in the network. These actors may simply fall away from the network’s set of operations, or they may actively work against the network’s success. Lastly, in the step of mobilization, the network functions together as a whole, also known as an actor-network, to complete the task given by the network builder. In my analysis, I determine how various rogue actors actively worked against the C-130’s actor-network and contributed in both the short and long term to the eventual crash in 2002.

Analysis

Four main “rogue actors" contributed to the failure of the wings in the C-130. First, there were the cracks in the structures themselves. Second, there was the military maintenance network recruited by Hawkins & Power Aviation (H&P) during the step of translation. Third, there was a passive culture surrounding the safety of aerial firefighting blaming a lack of funding for inadequate maintenance standards. Lastly, there were an increased number of wildfires during 2002, putting pressure on a network already stretched thin. These actors eventually decohered from the network and began working against the success of this aerial firefighting operation. They were not prioritized by the network builder, H&P, despite their potential to exert significant power over the success of this actor-network.

Large Cracks in the Wing

The cracks in the wings served as a rogue actor to the network due to the mechanical failure they directly caused. These cracks, which grew to over 12 inches long, extended visibly past the doublers they began underneath. They were located in the area called out for examination by maintenance staff in the inspection manual, but were still hidden underneath a layer that had to be removed to access (*NTSB accident summary for N130HP*, 2002). The cracks were also much larger than the size capable of being detected by the eddy currents used in inspection: 0.5 inches (*NTSB accident summary for N130HP*, 2002). Hawkins & Power, the company who acquired the aircraft, performed the necessary checks called out in their maintenance procedures, but the procedures themselves were flawed and over-predicted the time interval of safety between inspections that would uncover the cracks. The necessary “C checks” that would have found these cracks were performed six years prior in a “detailed 2400 hour inspection” (*NTSB accident summary for N130HP*, 2002, p. 13). Additionally, a large portion of the outer portion of the right hand wing was replaced on March 1, 2001 during the last, less detailed C check (*NTSB accident summary for N130HP*, 2002). These incompatible maintenance procedures gave H&P the false impression that the C-130 actor-network was stable and thus they deprioritized the inspections that could have prevented the crash. H&P maintenance staff were not specifically responsible for this, but the outdated procedures – governing the entire network since the C-130’s acquisition in 1986 – gave the false impression that the wings would last longer than they did. By prioritizing adherence to outdated procedures over caution, the cracks were allowed to exert extreme power within the C-130’s aerial firefighting network and destabilized it through the breaking of the wings and subsequent crash.

Incompatible Maintenance Network

The current fleet in the United States consists of repurposed cargo or transport aircraft that have already been in service and accumulated many flight hours before being used by the BLM or USFS. This leaves little room for mistakes in maintenance since a large portion of the aircraft's safe-life has been used already. As noted by the NTSB in their accident summary of the C-130 Hercules:

> C-130 Operational Loads Recording Programs has shown the firefighting missions to be substantially more severe than typical military logistics operations and consequently, aircraft operated in this role would require inspection intervals as much as 12 times more frequently than typical military transport usage for meeting damage tolerance requirements (p. 32).

Note how the NTSB recognized how different aerial firefighting operations are than military missions, needing up to 12 times more inspections. Aircraft performing firefighting operations experience higher maneuver loads during payload drops than the military maintenance procedures accounted for, and without more frequent inspections, will accumulate wear that can lead to these types of accidents. The C-130 Hercules exceeded the maximum load factor stipulated in the outdated military maintenance procedures (2.4 g's vs. 2.0 g's) during the maneuver that separated the wings, and likely did so many times throughout its lifetime (*NTSB accident summary for N130HP*, 2002). It also flew well beyond the prescribed 12,000 flight hours before inspections for cracks in the wings were required (*NTSB accident summary for N130HP,* 2002, p. 20). This requirement was not only ignored, but was also a mismatch, since the tests that produced these numbers assumed that the weather conditions and mission profiles were the exact same as when the C-130 Hercules was used by the United States Air Force (*NTSB accident summary for N130HP*, 2002). This is how Hawkins & Power Aviation failed to properly translate the military maintenance network for the acquired C-130's to a new purpose of aerial firefighting. I assert that Hawkins & Power completely skipped the action of "interessement" during their translation phase. Those responsible for evaluating the military maintenance procedures and aligning them with the necessary capabilities for aerial firefighting, rather than carrying them over unchanged, did not do an effective job.

Complacency and a Passive, Reactive Culture

As I have argued above, the incompatible maintenance procedures used by H&P to determine the safety of the C-130 Hercules directly led to the destabilization of the network and the C-130's crash. According to Cy Birr, a retired air force pilot, the C-130's flight history went undocumented for a span of four years in the 1960's before being acquired by H&P. In addition to inadequate record keeping, he believes the staff assigned to inspect the C-130 were inadequate in size and not paid at a level equal to the care they should have put into inspection (Leone, 2020).

The lapse in stringent maintenance over the years leading up to the C-130 crash in 2002 could be attributed to monetary constraints by those who share Birr's viewpoint. Aerial firefighting operates on a budget like every other airline, but it is increasingly harder to justify spending on the operation as a whole in their current state. Current options like the DC-10 have high operating costs: $4598-12,750 per hour as of May 2014 (*US Forest Service Fire & Aviation Management DC-10 Briefing Paper*, 2014). The effectiveness of aerial firefighting is even debated, and firefighting aircraft are not always in use since wildfires don't happen every day (*Aerial Firefighters & Fire Fighting: Dangerous… But Effective?*, 2021). This leads managers of the BLM or forest service to reallocate budgets for performance, efficiency, and cost-effectiveness rather than safety of the pilots flying the aircraft. Thus, money is taken out of the maintenance crew's budget, putting more pressure on them to perform and get the job done despite their limited resources. This leads to inadequate work being done and even falsified maintenance records, which have dire consequences. Furthermore, managers may be reluctant to allocate resources to maintenance crews since they do not appear to give an immediate return for the initial investment. This is only further compounded by the time it typically takes between accidents for fatigue to occur and cause mechanical failure. USFS and BLM managers have little incentive for a focus on safety besides a moral, cautionary stance that could, in the current culture, potentially get them fired due to poor performance on their budget (*USDA Forest Service and Director*, 2002). BLM and USFS managers' attitudes typically try to force as much service as possible out of an aircraft they obtain due to these budgetary constraints. This erosion of safety precautions leaves the network vulnerable to rogue actors and makes it easier for the pressure they put on the network to disrupt it and cause failure. “Culture creep” was not only present in the Alaska Airlines 261 crash two years earlier, but also within the USFS firefighting network.

A lack of funding may be a driver of decisions which remove safety precautions from the maintenance network, but it is not sufficient alone to explain the more important factors contributing to the C-130’s crash. I argue that we must consider these discrepancies between maintenance procedures and aerial firefighting missions in addition to a passive, reactionary culture which blames funding and doesn’t value safety until after a crash occurs.

While Birr’s analysis that maintenance was neglected due to poor funding appears valid on the surface, it neglects the contribution of continued usage of outdated and mismatched maintenance procedures to the crash. The continued usage of outdated military maintenance procedures destabilized the network over time, causing unnecessary loss of life in an operation designed to save people’s lives from wildfires. Damage and hours sustained under aerial firefighting missions are much different than typical military missions – fluid slosh, intense maneuvers, and high ambient temperatures are more common. By continuing to reuse outdated military maintenance procedures on an aircraft with over 20,000 flight hours (*NTSB accident summary for N130HP,* 2002), the critical cracks that caused failure went undetected and the

C-130 crashed. In order to properly support the network, these maintenance procedures must take into account the unique mission profile of firefighting aircraft as well as the age and modifications of such aircraft already in service.

To address this, USFS and BLM responded to the incident, grounding the entire fleet of large air tankers due to safety concerns. Their response was adequate, but was reactive rather than proactive. The reasoning behind their actions is summarized by a statement from the following Blue Ribbon Panel:

> Contractors have no financial incentive and are not required to ensure that their aircraft are safe to fly. A number of potentially viable options were routinely dismissed as too expensive before being carefully examined, perhaps reflecting this community's "no-money" state-of-mind…[this has] bred a culture that accommodates risk in aerial firefighting activities…[and] has translated to … insufficient training, inspection, and maintenance; and a deplorable safety record for large air tankers. (*USDA Forest Service and Director*, 2002, p. 22-23)

The Blue Ribbon Panel recognized that the "no-money" mindset directly led to a "deplorable" history of crashes among aircraft like the C-130 Hercules. This shows how flawed the thinking that Birr and others, including USFS and BLM managers, attribute towards the cause of this accident is. Having this "no-money" mindset leads to inaction and tolerance of sub-par safety standards, while also giving an excuse for the organization to point to and request more funding. This is a selfish, nearsighted business practice and completely disregards the safety of the pilots. A proactive mindset would instead prioritize safety over savings and do its best to catch as many flaws in equipment as possible before they are allowed to grow and cause a catastrophic crash. Taking the risk that USFS managers do and thinking that "it's ok to push the performance out of this aircraft because it hasn't failed yet" is an unacceptable practice in the field of aerial firefighting.

Although budgetary constraints are an easy issue to point to for explaining the failure of the wings, as are the cracks themselves, they do not adequately address the mismatched military maintenance procedures or the culture within the aerial firefighting community that accepts risk in their operations that typical transport airlines do not (*USDA Forest Service and Director*, 2002). If the culture that caused the crash is ever to be changed, a proactive approach towards safety and adequate, up to date maintenance procedures must be paramount.

The 2002 Wildfire Season

In addition to pressure from monetary constraints, the fire season of 2002 put the USFS aerial firefighting network under additional stress. This fire season was the 2nd largest in terms of total acres burned in the 50 years prior, with the year 2000 topping the list (*Wildfires and acres | National Interagency fire center*). In total, there were 8,329 fires in California during 2002 (*2002 Large Fires*, 2003) with 17 large fires occurring before the Cannon Fire, which the C-130 Hercules was responding to (*National Report of Wildland Fires and Acres Burned by State*, 2003). The Cannon Fire required many resources to put out, almost tripling in size from 5,000 to just under 15,000 acres in the 2 days since it began on June 15th 2002 (*Cannon fire in California and Nevada*, 2002). The C-130 Hercules was completing its sixth drop of the day on the Cannon Fire when its wings detached. It was also the only air tanker responding to the Cannon Fire since it began. This shows the network was being stretched thin and the USFS was being asked to force more performance from their C-130 and its crew than was safe to do. This also exemplifies the risk-taking nature of firefighting organizations mentioned by Stonesifer et al. in their Aviation Exposure Index research. Had the USFS not deployed the C-130 Hercules to the

Cannon Fire on June 17th, 2002, there would have been no fatalities associated with the fire. While the presence of wildfires is out of the USFS and BLM's control, the availability of their aircraft is and must be properly adjusted to adequately respond to fires when the need arises.

A Lack of Due Diligence

It can also be noted that in 1998, just four years before the C-130 Hercules's crash, the United States Air Force (USAF) released a report giving guidelines for Programmed Depot Maintenance (PDM) for C-130's. This process involves taking a C-130 out of service for several months and performing in-depth maintenance checks, including replacing components of the aircraft when necessary. Major Daniels created this report to re-evaluate PDM in 1998 due to the following reasons:

> [M]any C-130 operators and maintainers did not understand how the PDM intervals had been established over the many years of C-130 operations … (and) the current USAF process for establishing C-130 PDM intervals does not account for the wide range of aircraft variables within each aircraft MDS [Mission Design Series]. (Major Daniels, 1998, p. v-vii)

Notice how Major Daniels, the head of USAF C-130 maintenance in 1998, recognized inconsistent procedures for PDM intervals over varying mission requirements in the military. This shows that mismatched maintenance procedures were widespread among C-130's even in the military network that the C-130 Hercules came to the USFS from. He also understates the lack of general awareness in the USAF of the purpose behind appropriate intervals for C-130 maintenance. The report delivered an analytical model that provided a way to predict how long intervals between maintenance checks should be for optimal performance and longevity of the C-130. It did this based on data from "(the) aircraft('s) age, total flying hours, average yearly flying hours, mission profile (expressed as a severity factor), and operating location of the aircraft" (Major Daniels, 1998). These variables have a significant effect on the speed at which an aircraft wears out its parts, and must be considered when predicting how long an aircraft can go between maintenance checks. It is unknown if this report ever reached Hawkins & Power Aviation, the USFS or BLM, and if so, whether or not they used it in their operations. However, in the Blue Ribbon Panel, this statement was made regarding awareness of safety regulations in aerial firefighting:

> It appeared to the panel that Forest Service and BLM leaders were not well versed on aircraft certification, airworthiness, and performance issues, nor their implications for flight safety. (*USDA Forest Service and Director*, 2002, p. v)

Both the Blue Ribbon Panel and Major Daniels observed how, at the time, leaders and operators of C-130's had little awareness of the purpose and importance of maintenance procedures. Proper maintenance procedures directly influenced the safety of their operations, and the lack of effort put forth by C-130 operators to understand them and adapt them to their specific C-130's mission shows how little concern they had for safety. Considering how concerned the USFS and BLM were about the cost of safety programs, as I have shown above, it is perplexing that they did not seem to consider an aircraft crash at all. Completely losing an aircraft and its crew through a crash is much more detrimental to an organization than regular maintenance intervals, and had the USFS and BLM prioritized long-term safety over short-term savings, this crash could have been avoided.

Conclusion

In order to effectively address the problem of more intense and numerous wildfires worldwide via aerial firefighting, the social aspects which support the operation of firefighting aircraft must be taken into account. Maintenance and safety must be seen as a primary objective during a firefighting operation by both the FAA and firefighting leaders. Complacency over funding directly leads to an erosion of the safety network in place, and must be halted at its onset when warning signs are identified if the culture that caused these crashes is ever to be changed. Aerial firefighting managers and organizations must give the pilots considerable care and must make safety their utmost priority despite pressure beyond their control. A better understanding of the social factors which contributed to the Lockheed C-130 Hercules crash in 2002 near Walker, California has been discussed in this paper through analysis using Actor Network Theory. For such a network to avoid the failures of the past, it must anticipate and terminate culture creep before it can take hold, and constantly assess and re-evaluate its maintenance procedures as the network evolves beyond its original formation.

References

2002 Large Fires. (2003). CAL FIRE. https://www.fire.ca.gov/fire_protection/downloads/LF2002.pdf

Aerial firefighters & fire fighting: Dangerous… but effective? (2021, February 25). Frontline. https://www.frontlinewildfire.com/aerial-wildfire-fighting-how-effective-is-it/

Callon, M. (1986). Some elements of a sociology of translation: Domestication of the scallops and the fishermen of St Brieuc Bay. *Power, action and belief: a new sociology of knowledge?*, 196-223. https://collab.its.virginia.edu/access/content/group/2c3f2747-0edf-43e1-99fe-51ac419aa129/Readings%20-%20Frameworks/Actor%20Network%20Theory/Callon.DomesticationoftheScallops.pdf

Cannon fire in California and Nevada. (2002, June 19). NASA Earth Observatory. https://earthobservatory.nasa.gov/images/9761/cannon-fire-in-california-and-nevada

Cressman, D. (2009, April). *A brief overview of actor-network theory: Punctualization, heterogeneous engineering & translation*. UVA Collab 21F STS 4500-010 (ENGR). https://collab.its.virginia.edu/access/content/group/2c3f2747-0edf-43e1-99fe-51ac419aa129/Readings%20-%20Frameworks/Actor%20Network%20Theory/Cressman.OverviewANT.pdf

Leone, D. (2020, June 16). *The sad story of tanker 130, the C-130 whose wings fall off during the 2002 fire season*. The Aviation Geek Club. https://theaviationgeekclub.com/the-sad-story-of-tanker-130-the-c-130-whose-wings-fall-off-during-the-2002-fire-season/

Major Daniels, J. A. (1998). *C-130 Programmed Depot Maintenance* (Air Command and Staff College Wright Flyer Paper No.1). USAF. https://permanent.fdlp.gov/lps40033/wf01.pdf

Mak, A. (2021, August 8). *The reason we don't have enough airplanes to put out wildfires*. Slate Magazine. https://slate.com/business/2021/08/california-wildfires-airplanes-dc10-shortage.html

National Report of Wildland Fires and Acres Burned by State. (2003). National Interagency Fire Center. https://www.predictiveservices.nifc.gov/intelligence/2002_statssumm/fires_acres.pdf

NTSB accident summary for N130HP. (2002). National Transportation Safety Board. https://en.wikisource.org/wiki/NTSB_accident_summary_for_N130HP

Schnedler, C. G., Murphy, D., Stump, S. J., & St. Phar Stevens Institute of Technology, F. (2007). Alaska Airlines Flight 261: Understanding the systemic contributors to organizational accidents. *Systems Research Forum, 2, 42-51.* http://www.josephrlaracy.com/srf.pdf#page=46

Stonesifer, C., Calkin, D., Thompson, M. P., & Kaiden, J. D. (2014). Developing an aviation exposure index to inform risk-based fire management decisions. *Journal of Forestry*, *112*(6), 581-590. https://academic.oup.com/jof/article/112/6/581/4599033?login=true

Testimony. (2003, March 26). *Statement of Larry Hamilton National Director, Office of Fire and Aviation Department of the Interior, Bureau of Land Management National Interagency Fire Center Oversight Hearing: Blue Ribbon Panel Report and Aerial Firefighting Safety Senate Energy and Natural Resources Committee Subcommittee on Public Lands and Forests*. US Forest Service. https://www.fs.fed.us/congress/108/senate/oversight/hamilton/032603.html

USDA Forest Service and Director. (2002). Federal aerial firefighting: Assessing safety and effectiveness. *Blue Ribbon Panel Report to the Chief, USDI Bureau of Land Management.* https://wildfiretoday.com/documents/Blue_Ribbon_Panel_Final_12-05-2002.pdf

US Forest Service Fire & Aviation Management DC-10 Briefing Paper. (2014, May 1). https://www.nifc.gov/nicc/administrative/nmac/L-14-13%201_DC-10BriefingPaper.pdf

West, P. (2004, May 12). *Feds terminate large air tanker fleet*. Wayback Machine. https://web.archive.org/web/20070929131320/firechief.com/wildland/large-air-tankers/

Wildfires and acres | National Interagency fire center. (n.d.). https://www.nifc.gov/fire-information/statistics/wildfires