

RESEARCH ARTICLE

No second-in-command: human fatigue and the crash of the airship *Italia* revisited

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Abstract

The dirigible *Italia* crashed onto the Arctic sea ice north-east of the Svalbard archipelago on 25 May 1928 at 10:33 GMT while travelling back to her base from the North Pole. Only eight of the 16 crew members survived: one was killed upon impact, one did not survive the post-crash ordeal and six were trapped in the airship envelope (i.e., the balloon), which floated away and disappeared. No definite conclusions have ever been reached about the causes of the crash. The judgements of the Commission of Inquiry instituted by the Italian government and published in 1929 are carefully examined. Recent analysis has presented evidence that the mishap may have been fatigue-related. In this paper, the pivotal question of why General Nobile was so sleep-deprived at the time of the accident is addressed, specifically with reference to the lack of a second-in-command (i.e., a deputy commander) during the flight. Such a position was a standard practice for airships at the time, and General Nobile himself described this position as one necessary for an airship. Nevertheless, for a variety of reasons he proceeded on the *Italia* expedition without an official crew member responsible for this role. The lack of a second-in-command is proposed as a possible major contributing factor in the overall sequence of events leading to the crash of the *Italia*, although other possible causes and contributing factors for the crash are also considered, including structural failures, crew selection and political obstacles.

Introduction

The cause of the airship *Italia* disaster remains an unsolved question that continues to hold great interest among historians, even though the event has now reached its 91st anniversary. The *Italia* crashed onto the sea ice at 10:33 GMT on 25 May 1928 while en route from the North Pole back to her base of operations. Only eight of the 16 crew members survived: one was killed upon the impact, one did not survive the post-crash ordeal and six were trapped in the airship envelope that, relieved of the weight of the control gondola beneath it, floated away after impact and soon disappeared. A multinational search and rescue effort ensued, and the survivors were eventually rescued. Despite the official investigations, survivor memoirs and speculative studies that have produced an impressive bibliography since that time, no definite conclusions have been reached regarding the causes of the crash.

Recent analysis on the human factors involved, and in particular regarding the orders that were given by her

commander General Nobile before the crash, has presented relevant historical evidence demonstrating that the mishap may have been fatigue-related (Bendrick et al. 2016), specifically that it was caused by a lack of sleep on the part of the commander. Fatigue is notoriously regarded as a major cause of degraded neurocognitive performance and increased error and is a significant problem in modern aviation operations (Caldwell et al. 2009).

This paper adds to the prior study by focusing on the pivotal question of why General Nobile was so sleep-deprived at the time of the mishap. Addressing the question with reference to primary historical sources, the authors point to the lack of a SIC on the *Italia* as a main reason for sleep deprivation. Designating an SIC was a standard practice from the earliest days of airship aviation in order to provide the commander with periods of much-needed rest and sleep; the SIC would also take control of the airship if the commander was otherwise unavailable. General Nobile himself stated as much in two separate technical papers written in the early 1920s. One may

Keywords

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Abbreviations

CDUN: Umberto Nobile Documentation Centre
MM: Ministero della Marina (Navy Ministry)
RSGI: Italian Royal Geographical Society
SIC: Second-in-command

therefore ask two relevant questions: (1) Why was this position never officially filled for the *Italia* on her polar exploration flights? (2) Did General Nobile make this explicit choice by himself, or were there other factors that impacted this decision?

Other causes or contributing factors to the crash are also considered. These include a structural failure and/or a failure of the ship's envelope or gas bags. With respect to the most likely physical failures it is evident that the decisions made by the commander in the period of time before the crash would have greatly contributed to the failure. So, the examination of the underlying reasons for the commander's fatigue is of significance.

Since the major goal of the *Italia* expedition was the pursuit of scientific knowledge, it is worthwhile to extract everything that can be learned from this endeavour so as to apply it to the future exploration operations. That is indeed the best way to commemorate the memories of the *Italia* crew members, including her commander. It is in this spirit—one of true respect and admiration rather than of obsolete criticism—that this work has been written.

Narrative

Umberto Nobile (1885–1978) was an aeronautical engineer, a leading airship designer and constructor as well as a dirigible pilot, who achieved the rank of Lieutenant General in the Regia Aeronautica (the Italian Air Force). After the success of the Amundsen–Ellsworth–Nobile Transpolar Flight in 1926, Nobile considered another ambitious flight by airship to the Arctic. This time the endeavour was not limited to passing over the Arctic basin but was meant to search for lands and to conduct scientific experiments. He planned several scientific and exploration flights over different Arctic areas, each originating from Ny-Ålesund, a small mining settlement at Kongsfjorden, then known as Kings Bay in the Svalbard islands. One destination of these flights was intended to be the North Pole, where the intention was to discharge a scientific party to perform research. The scientific party would be later retrieved using the same dirigible.

The enterprise, entitled the Italian Expedition for the Aerial Exploration of the Arctic Regions, was flown under the Italian flag, financed by the city of Milan and sponsored by the RSGI. Nobile was appointed in charge of the technical and scientific organization in concert with the RSGI. After an initial attempt to employ a much larger airship that was under construction, Nobile eventually had to make do with the N-4 semi-rigid airship almost identical to the N-1 *Norge*. The N-4 was adapted for the polar flight and named the *Italia*. Both airships were built largely at the Aeronautical Construction Establishment, the Italian state

airship factory in Rome, and assembled at the aero shipyard of Ciampino aerodrome (Alessandrini 2019). The crew mainly comprised Italian *Norge* veterans and members of the Regia Marina (Italian Royal Navy, which supported the expedition) as well as scientists. Once preparations were complete, Nobile and his crew lifted off from Milan, Italy on 15 April 1928, headed to the base at Kings Bay, where the roofless hangar and the mooring mast used by the *Norge* had been restored. Already en route to Kings Bay was the support ship *Città di Milano*, supplied by the Regia Marina.

The *Italia* encountered a variety of obstacles and delays due to poor weather and damage during the multiple-leg flight. This caused a more prolonged first-stage stop at the German aerodrome of Stolp by the Baltic Sea as well as the planned restocking stop at Vadsø, Norway, but they finally reached their destination on 6 May 1928. The first flight over the Arctic was initiated on 11 May 1928, but they had to return after only eight hours because of a deteriorated elevator control cable and the extreme environmental conditions. By 15 May 1928 the weather conditions had improved; they repeated the endeavour and this time the attempt was successful. They flew over largely unexplored regions, from Svalbard to Franz Joseph Land and Severnaya Zemlya, carrying out the planned scientific observations. When strong gusty wind from the north prevented them from continuing eastward, they headed south for the Novaya Zemlya archipelago, which was reached at 04:20 GMT on 17 May. The *Italia* flew over long stretches of the east and west coasts of Severny Island and then began its return flight over the Barents Sea. After having flown over Nordaustlandet and the northern part of Spitsbergen, the *Italia* landed at her base on 18 May at 10:20 GMT, after a 4000-km flight that lasted 69 hours.

The pivotal flight of the *Italia* occurred when it was launched on the polar mission early in the morning of 23 May 1928. In addition to Commander Nobile there were 15 crew members (Table 1). The *Italia* first approached the northern coast of Greenland (Cape Bridgman) and from here the airship reached the Pole at 00:20 GMT on 24 May 1928, but unfortunately the winds there were too high to safely land a scientific party. So, after a brief ceremony in which the Italian flag and the Pope's cross were dropped on the Pole, the crew began the arduous journey back to base, facing strong and persistent head winds as well as fog and ice encrustations on the envelope. On the morning of 25 May 1928, at about 09:25 GMT, the airship suddenly began to lose altitude because a jammed elevator-wheel control mechanism (the fixator) was stuck in the downward position. Recognizing the seriousness of the problem, Nobile ordered all engines to stop in an attempt to reverse the uncontrolled descent. Without forward thrust generated by the engines (i.e., dynamic lift) the ship's descent did slow down, and eventually stopped

Table 1 Members of the airship *Italia* expedition who were part of the polar mission that started on the morning of 23 May 1928.

Position	Name	Nationality	Age (years)	Task	Remarks
Commander	Umberto Nobile	Italian	43	Pilot	Expedition leader
Officers	Adalberto Mariano	Italian	30	First officer; navigator	
	Filippo Zappi	Italian	31	Second officer; navigator	
	Alfredo Viglieri	Italian	28	Third officer; helmsman	
Crew	Felice Trojani	Italian	31	Elevator-wheel steersman	Engineer
	Natale Cecioni	Italian	41	Chief technician; elevator-wheel steersman	
	Ettore Arduino ^a	Italian	38	Chief mechanic	
	Calisto Ciocca ^a	Italian	31	Mechanic (starboard engine gondola)	
	Attilio Caratti ^a	Italian	33	Mechanic (port engine gondola)	
	Vincenzo Pomella	Italian	30	Mechanic (stern engine gondola)	Died 25 May 1928 because of the crash
	Renato Alessandrini ^a	Italian	38	Rigger; helmsman	
	Giuseppe Biagi	Italian	31	Wireless operator	
Scientists	František Běhounek	Czech	31	Physicist	
	Finn Malmgren	Swedish	33	Meteorologist	Died in an attempt to reach Nordaustlandet from the site of the “red tent.”
	Aldo Pontremoli ^a	Italian	31	Physicist	
Journalist	Ugo Lago ^a	Italian	28		

^aLost with the envelope on the day of the crash.

at about 80 m (262 feet) above the sea ice, thereby avoiding impact. The airship then began to rise because of the buoyancy produced by the ship's hydrogen gas (i.e., static lift). While chief technician Cecioni was checking the control mechanism, Nobile had already opened all ballonet outlet air valves, allowing the hydrogen lift gas to expand freely during the ascent. As they continued to rise, the gas pressure increased and at some point Nobile had to release some amount of gas to control the lift. Then, before re-starting the engines, Nobile agreed to a suggestion by first navigating officer Mariano to ascend above the fog and clouds in order to obtain a sextant reading on the sun, providing a partial navigational fix to their location, as they were uncertain about their position. To get above the clouds they had to climb to an altitude of approximately 2700 feet. This would cause a further expansion of hydrogen and a subsequent increase in pressure inside gas bags in accordance with the ideal gas law (i.e., when a gas is enclosed within a container of fixed size, the pressure of the gas would increase with increasing altitude). In addition, while in the direct sunlight above the ice fog and clouds the sun rays heated the envelope and the gas inside the bags, thereby causing the hydrogen volume to expand even further. In fact, the hydrogen of the airship had expanded to such an extent that it completely filled the envelope (Nobile 1945). This means that the airship had most likely reached “pressure height,” the altitude at which the internal pressure of the gas bags equals the atmospheric pressure. The pressure height is the limit for structural integrity of an airship and can be surpassed only by releasing hydrogen lift gas. To avoid catastrophic

consequences, the airship's gas bags were equipped with controlled and automatic pressure relief valves that opened when the internal pressure reached a specified level.

The *Italia* spent approximately 30 minutes with the engines turned off and remained above the clouds layer for about 20 minutes. After restoring the elevator wheel control, at 09:55 GMT Nobile ordered the engines to be restarted to resume the trip towards their base and, after a while, to descend back under the clouds. The airship continued her trajectory until they could see the frozen sea at about 300 m (980 feet) in altitude to verify speed and drift.

Afterwards, at 10:30 GMT, the *Italia* began to lose altitude once again but this time it was due to an overall loss of lift, i.e., the airship had suddenly become “heavy.” Nobile ordered the three engines at full speed to maintain dynamic lift, but this action was unable to correct the downward motion. The airship then became uncontrollable. So Nobile commanded that the ballast chain be dropped, the gas valves on the top of the envelope be checked, and finally, the engines be shut down. Nevertheless, the *Italia* crashed onto the Arctic pack ice north of Nordaustlandet, Svalbard, at 10:33 GMT on the morning of 25 May 1928. It was approximately 300 km north-east of Kings Bay.

Upon impact, the upper part of the airship, which comprised the envelope and its inner metallic structure containing several large bags of hydrogen and other supplies, as well as six crew members, was sheered away from the smashed control gondola, with only its left wall remaining attached to the girder. The envelope—with the crew members on board—floated away like a free balloon and disappeared, never to be seen again; their resting

Table 2 Final moments of the airship *Italia* on 25 May 1928, approximately 180 nautical miles north-east from her base at Kings Bay. Some information presented below concerning the *Italia*, about becoming like a free balloon after the crash, is purely conjectural, other information has been taken from the survivors' cited literature or from the Commission of Inquiry report (in italics).

Time	Ca. 10:27 GMT	10:30 GMT	10:33 GMT	Ca. 10:33 GMT
Cruising conditions	Under cloud layer	Uncontrolled descent	Impact forward sea ice	Beginning of uncontrolled ascent like a free balloon
Buoyancy	Light/ <i>static equilibrium</i>	Heavy	Heavy	Light (temporarily)
Attitude	Slight nose-down	Stern-down (8° initial) (<i>40° final</i>)	<i>Stern-down (at first)</i>	Stern-down (40°)
HDG ^a	230°–240°	<i>Variable, rotating 180° to the left</i>	50°–60°	80°–140° (drift direction)
GS ^b	55 km/h	<i>70 km/h (average speed)</i>	<i>100 km/h (impact)</i>	25–35 km/h
IAS ^c	80 km/h	<i>40–100 km/h</i>		Not applicable
Height (a.s.l.)	300 m	<i>250 m (initial)</i>	0 m	100 m and beyond in the fog
Wind	<i>260°–270° 30° at prow</i> 25 km/h (decreasing from 40–50 km/h)	Variable in intensity and direction	<i>260°–270° at stern</i> 4–6 km/h (reported at ice surface)	260°–270° at stern 25–35 km/h
Motors	2	3/1400 rpm	Off	Off/destroyed
Descent rate	Not applicable	0.5 m/s (initial) <i>1.5–3 m/s (final)</i>	Not applicable	Not applicable
Weather	Fog, snow gusts			Foggy

^aHeading. ^bGround speed. ^cIndicated air speed.

place has never been located. The final moments of the *Italia* flight are summarized in Table 2. Meanwhile, at the site of the crash one crewman (the motorist at the stern engine gondola) lost his life because of the injuries consequent to the impact; nine others controlling gondola survived on the pack ice. Several sustained injury, including Nobile, who was the most seriously wounded crew member. The group gathered what provisions and equipment they could find from the contents of the airship that had been strewn across the pack ice and began the task of survival on the floating ice in the hope of rescue.

The support ship, which had lost radio contact, began organizing reconnaissance operations on the evening of 25 May 1928. Since the *Italia* had not sent an SOS distress signal prior to the crash, these first reconnaissance operations were focused on the last known position of the *Italia*. Meanwhile, the emergency airship's shortwave radio was recovered by the survivors, who used it to request help, though a long while passed before their signals were received. (Their signals were intercepted for the first time on 3 June 1928 by a Russian amateur radio operator near Arkhangelsk, who reported their status to the Soviet authorities.) After a few days the radio link was well fixed with the Italian support ship as well, and the position of the survivors' "red tent" was clearly identified on 8 June 1928.

Many countries joined in the multinational search and rescue effort that ensued. Roald Amundsen himself initiated his own private airborne effort, commissioning a French seaplane (Latham 47) for the task. Unfortunately, he was lost in the attempt; he and his French–Norwegian crew were never found. The *Italia* survivors were eventually spotted on 20 June 1928 by a seaplane of the Regia Aeronautica, piloted by Umberto Maddalena. Later a Swedish pilot, Einar

Lundborg, was successful in landing on the ice near their survival camp. His aircraft had room enough to transport only one survivor at a time, and Nobile was the first one to be rescued—a choice that was later considered unjustifiable by the Italian official inquiry and quite controversial abroad (Aas 2005). On his second flight to the survivors, Lundborg crashed on landing and became one of those awaiting rescue. Eventually, on 12 July 1928, a Soviet icebreaker, the *Krasin*, made its way to the survivors and retrieved all of them, apart from Malmgren, who had died in an attempt to reach Nordaustlandet. The rescue occurred 49 days after the crash (Giudici 1928; Tomaselli 1929; Viglieri 1929; Maddalena 1930; MM 1930; Nobile 1930; Samoylovich 1930; Trojani 1964; Ferrante 1985; Cross 2002).

The inquiry and the cause of the crash

After the return of Nobile and the other survivors, the Italian government instituted a Commission of Inquiry to investigate the cause of, and responsibility for, the accident. The commission's chair was entrusted to Admiral Cagni, who had prior experience with a ground-based polar expedition led by the Duke of the Abruzzi (1899–1900). The investigations, which were carried out from 12 November 1928 to 27 February 1929, were based on documents (e.g., the airship's logbook, several official reports, telegrams and publications) and statements of the main rescuers, authorities, journalists and the survivors of the *Italia*. The results of the inquiry were made public on 3 March 1929 by the MM and were later published in book format (MM 1930). The first part of the report, which concerns the "causes that determined the loss of the airship," was accompanied by a

technical treatise from General G.A. Crocco, who was an aeronautical scientist and a pioneer of dirigibles.

The commission's conclusions were critical of Nobile in virtually every aspect of his command of the expedition. General Crocco determined that "the management of the airship at the time of the alarm until the end was uncertain and contradictory" (MM 1930: 41; authors' translation) on the part of Nobile; he also highlighted the fatigue of the crew at that last, decisive moment. This technical advisor specifically faulted Nobile for not keeping the prow of the airship against the wind, and as a result allowing the wind to drive the airship into the sea ice at approximately 100 km per hour. He concluded his report by stating the following:

If, from the proximate causes of the catastrophe (more-over indeterminable), which could be called its specific *trauma*, it goes back to the ultimate causes where it was potentially contained, one cannot but find them in the *structural composition* of the crew and in the uncertain distribution of tasks and responsibilities among its members. Above all, a skilled pilot, possessing that trained capacity acquired only by a long course in navigation, was lacking on board. (MM 1930: 41–43; authors' translation; italics in the original)

This final passage of the report is very important because here General Crocco admits that the cause of the disaster is not determinable. Moreover, he makes an important distinction between the unknown "proximate causes" that ultimately led to the accident and the "ultimate causes," i.e., the latent failures within the causal sequence, which in this case were assumed to be the management of the crew and the commander's piloting skills. In any case, the commission wanted to draw absolute conclusions about the crash from the findings they had gathered. Stating the unanimous conclusion of the inquiry, the report read as follows:

The precise responsibility for the disaster rests on the commander of the airship *Italia* for erroneous manoeuvres ... Throughout the operation of the expedition up to the disaster and after, General Nobile has shown himself to have limited technical qualities as a pilot and a negligible capacity for command. (MM 1930: 21–24; authors' translation)

After the inquiry, Nobile resigned from the Regia Aeronautica and went abroad, settling first in the USSR (1931–1936) and later in the USA (1939–1942).

Of note, General Crocco's assessment was conducted mainly on the statements of the survivors, since there was no wreckage or other evidence of structural or mechanical failures to examine. So the "human factors" was the only

area on which the investigation about causation could focus. However, this did not mean that human factors were the only possible underlying causes. For instance, it cannot be ruled out that the final descent was due to a ripping of the outer cover, which would lead to a consistent loss of gas from the aft gas bags, as had happened just before the last flight (MM 1930). Likewise, there are similarities with another famous airship accident, that of the British HMA R101, which occurred in 1930, and was the subject of a thorough investigation. This investigation concluded that "the disaster was caused by a substantial loss of gas" due to "the ripping of the forepart of the envelope" from an undetected split (Anonymous 1931: 290). Similar to the *Italia*, from the moment the elevator was applied to counter the nose-down attitude of HMA R101, it took about 2–3 minutes for that airship to impact the ground.

Among the "erroneous manoeuvres" as a possible cause of the crash, it is worth recalling General Crocco's hypothesis, which was that of excessive air entering through the "valvolone" which could have been left unattended and open by the crew (MM 1930). However, this assumption by Crocco was wrong because any excess in volume or pressure of incoming air would have been drained by the outlet valves automatically, and the "valvolone" by design let in a small amount of air even when it was closed (Trojani 1964). The indispensable condition for Crocco's assertion was that of an impediment to air discharge. In fact, in their testimony to the Commission of Inquiry, General Nobile and crew member Trojani—also an engineer and airship designer—advanced an alternative hypothesis for the crash; they supposed a blockage of the discharge ducts of the stern air compartments, which were part of the ballonet, that is, the series of internal bags filled with outside air that were used to maintain both the shape of the airship and a constant lift gas pressure (MM 1930). These devices need to freely expand and contract when the air density, atmospheric pressure and temperature are all changing as a function of altitude. A consequent obstruction, resulting from ice encrustations or excessive length with extreme bending, would have caused first an overpressure condition of the gas and then an off-gassing through the automatic valves. A long time later Trojani returned to the same topic, and besides remembering that the gas pressure of the stern compartments was very high during the crash, he clearly stated that the gas manometers were totally unreliable when bad weather conditions caused the airship to pitch, as often happened during Arctic navigation (Trojani 1964).

Also, with respect to the investigation, the memories of the survivors may not have been entirely accurate, as their statements were often contradictory (Crocco 1945). Generally speaking, eyewitness testimony is often less than fully reliable because many variables are known to influence its accuracy, for instance, simply by talking

about the event can alter the recalled accuracy (English & Kuzel 2014). In this case the survivors' statements about the last hours of flight may have been inaccurate because they were made by men who at the time of the events were severely fatigued, and who had later suffered the physical and psychological trauma of the crash, followed by a 49-day survival period in the Arctic. Additionally, these witnesses were collected by the Commission of Inquiry several months after the tragic event. It is now known that safeguards are needed to prevent and reduce eyewitness error because post-event information from a variety of different sources—such as other eyewitnesses and the media (radio and newspaper at that time)—can permanently alter the eyewitness's memory as time passes. It is also worth noting that many factors could increase an eyewitness's confidence but not his or her accuracy (Wise & Safer 2012). To make matters worse, survivors and witnesses were not questioned about the same events or asked the same questions. There was no cross-examination, and the interrogated were not asked for any clarification. Moreover, the minutes of the interrogations were not published, and those questioned were not called upon to confirm and countersign the minutes (Trojani 1964).

Furthermore, when reading the commission's conclusions, it is important to remember the political context. At that time there were marked political divisions between those who favoured lighter-than-air vehicles and those who preferred heavier-than-air aircraft as the more effective means for the utilization of national air power (Zani 2003). It would arguably be of political advantage to those who favoured airplanes to show that airships were inherently less safe than the heavier-than-air aircraft, and the *Italia's* accident certainly provided an opportunity to do so.

According to the commission, Nobile should have followed "normal piloting rules" and performed these manoeuvres in order to stop the descent: (1) Put all the engines at full speed; (2) pitched the nose up by actuating the elevator wheel; (3) kept the bow of the airship "exactly" against the wind; and (4) thrown all available ballast off, and as an alternative manoeuvre: (5) stopped all engines and (6) performed a static descent with the bow in the wind. It seems rather ironic to accuse in this way a pilot who had flown continuously against the wind for many hours returning from the North Pole. Yet the commander did do all of the manoeuvres except one: Keeping the prow in the wind during the uncontrolled descent towards the sea ice. But this failure was a consequence of the fact that the airship was no longer responding to commands. In fact, the airship's attitude (30°–40° stern-down) resulted in an excessive inclination of the axis of rotation of the rudder (positioned below the tail)

that made it ineffective. This attitude corresponded to the stall position of the airship and could have been reached by an excessive compensation during the dynamic lift with the elevator in the "hard-up" position (due to the elevator-wheel steersman's inattention or poor technique). Therefore, if the main piloting accusation was based on this line of reasoning, it was clearly erroneous.

Moreover, the overall charge that Nobile was inexperienced and inept as a pilot appears ill-founded. He was an accomplished aeronautical engineer and a pilot, who at the time of the crash had accrued more flight time than anyone else with a semi-rigid airship in the unforgiving environment of the Arctic. The allegations therefore suggest that other factors, such as political rivalries, prompted at least some of the Commission of Inquiry's conclusions.

Nobile later indicated that his main adversary in this ordeal was Italo Balbo, who was the undersecretary of state for the ministry of aeronautics (the minister in charge was the head of the government, Mussolini) and a very influential politician during the regime (Zani 2003). Nobile felt Balbo had influenced the investigation as he pleased (Nobile 1945), and there is some merit to this supposition. From the very beginning Balbo had supported the expedition only reluctantly (Segrè 1990). He did not intend to do much more than grant the dirigible N-4 to the project because the expedition was not in keeping with his aviation policy, as he himself stated before the commission on 13 November 1928 (copy of the report kept at the CDUN; position XIII/18, "Italia" N4, 1928). During his testimony, he stated that he had proposed that airships be eliminated from the service because he believed they did not have any useful military application. For this reason, he was against the construction of new airships and was opposed to Nobile's polar expedition. He therefore denied financing the operation, or in any other way having any responsibility for the polar enterprise. As Balbo told Nobile: "The [Regia] Aeronautica cannot give a penny for this expedition." However, once the expedition was undertaken under the patronage of the RSGI, and financed by entrepreneurs of the city of Milan, many of the Regia Aeronautica resources—such as the Aeronautical Construction Establishment and the Meteorological Office—were put at General Nobile's disposal. Balbo himself took part in all the organizational meetings. It should also be pointed out that after the crash Balbo sent seaplanes and his best pilots available, such as Maddalena and Penzo, to participate in the rescue operations.

Yet his fundamental reluctance to the airship effort was still manifested by various other decisions. For instance, during the planning for the expedition Balbo denied the use of one large seaplane (a Savoia-Marchetti S.55) in support of the effort as well as the use of smaller seaplanes (Savoia-Marchetti S.59) transported on the

support vessel. He even refused the free offer made by the Caproni company of one Ca.73 aircraft, as evidenced by the correspondence from the Director of the Construction and Procurement Department of the Ministry of Aeronautics, General A. Guidoni (on behalf of Balbo), to General Nobile and G. Roncagli, Secretary of the RSGI (archive of the Umberto Nobile Museum in Lauro, Italy, document Nos. 889, 893 and 894). Therefore, the conclusion of the inquiry regarding Nobile must be understood against this backdrop of political agendas and personal rivalries. In fact, after the fall of the regime (1943) and the end of World War II, Nobile's reputation was rehabilitated, and he was portrayed as a victim of fascism. He was then reintegrated into the roles of the Italian Air Force (Ferrante 1985).

General Nobile, referred to in public opinion as the "guilty party," spent much of the rest of his life explaining and justifying his conduct through various writings published in both Italy and abroad. In his book *With the Italia to the North Pole*, a published account of the flight written shortly after the accident, first in Italian (1930) and the following year in English, Nobile describes in some detail what he himself thought to be the cause of the crash:

After long reflection, examining and weighing up the various arguments and all the circumstances of the catastrophe, I at last concluded that perhaps it was caused by two factors coinciding: a thick ice-crust, probably formed as the cold dirigible passed through a zone of warm, damp air, weighing down the ship (which had been very light), and an almost simultaneous loss of gas at the stern. The latter would be due either to several valves being forced open by the high pressure that Trojani noticed, or to the envelope being torn by a tube breaking in the framework. This is the most likely hypothesis, amongst the very few that tally with the only two facts of which we are quite certain; that a few minutes before it fell the ship was light, and that it increased in weight so rapidly that the crash was inevitable. (Nobile 1931: 184–185)

However, no definite conclusions have ever been reached about the causes of the crash. The variation in static condition from "light" to "heavy," which signalled that the beginning of the end, was very rapid. This could have been due to a loss of hydrogen lift gas for the reasons explained in a prior publication (Bendrick et al. 2016). Other considerations suggest that structural failure may have occurred, which could have resulted in a significant hydrogen leakage. In fact, as already mentioned above, a tearing had occurred in the stern sectors of the *Italia* shortly before lift-off of the last flight and was promptly

repaired. It is possible that the same tearing had reopened during flight, or that new ones had formed, causing the aft gas bags to be exposed and damaged by excessive strain. This would cause *Italia* to become "heavy," especially at the stern, and would quickly make it impossible to manage the ship with the elevator. Also, envelope deterioration could have been caused by the heavy snow clearing operations on top of the airship, which was accomplished using inappropriate means on the days before the last mission. Of note, any deterioration in the envelope or in the material of the gas bags would have been considerably worsened by the manoeuvres of taking the ship to altitude above the clouds and allowing it to be heated in the direct sunlight, factors which are discussed in more detail later.

Nobile focuses specifically on the relief gas valves and notes that because he feared that ice had formed on the valve seats and had rendered them unable to close, which would explain the sudden change in static condition, he had ordered the rigger Alessandrini to check the automatic valves as the airship began her final descent (Nobile 1930, 1961). The result of a frozen valve would indeed be a sudden, involuntary loss of hydrogen lift gas, followed by an uncommanded descent that might not be reversible (Nobile 1961). The phenomenon of frozen valves had occurred several times in the past with other Italian dirigibles that flew in winter environments, or flew at the higher and colder altitudes. It was also a problem known to have occurred on English airships (Nobile 1961). Therefore, the frozen valve hypothesis is at face value a plausible explanation of cause. In this instance, Nobile presumed the valve had become frozen while re-entering the fog bank after the crew had obtained the sextant reading while flying above the cloud layer.

However, frozen valves were most likely not responsible for the crash of the *Italia* for several reasons. First of all, ice encrustations are more likely to occur when a very cold object crosses a warmer and more humid area. In the case of the *Italia* it was just the opposite: The airship came from direct exposure to sunlight, where it had been heated, then she descended into the colder cloud layer and icy fog. Similarly, crew member Trojani, who was in the ship's control gondola monitoring the pressure gauges, recounts no sudden or significant loss of gas pressure that would occur when one or more valves became frozen in the open position (Trojani 1964). It is important to note that in the hours preceding the crash he was one of the elevator-wheel steersman, who had the fundamental task of gas and air pressure regulation, including manoeuvring the wheel of the "valvolone" (to adjust the front air inlet, which supplied ballonets) in addition to control pitch and altitude. On board of the *Italia* this steersman stood in the control gondola sideways,

facing starboard, acting on the elevator wheel and relying on various instruments (e.g., pressure gauges, altimeter, inclinometer and variometer). In the last two hours of the flight there were three crew members that alternated in this position: Trojani, Cecioni and finally Zappi.

Secondly and more importantly, a frozen valve was unlikely because of the very design changes innovations that Nobile himself had developed for his Arctic-crossing airships. He discusses his unique design as follows:

I had been studying the phenomenon since 1916, without being able to put my finger on its causes. I had not succeeded in determining in what measure the intrinsic humidity of the hydrogen and that of the surrounding air contributed towards ice formation. The best thing to do was to provide against both, so far as it was possible. This was done, partly by using hydrogen compressed to the density of several tens of atmospheres, and partly by covering each group of valves (which were placed on the back of the ship) with a light cap which protected it against the external humidity. (Nobile 1961: 273–274)

Furthermore, this phenomenon of a frozen valve had never been experienced either during the *Norge* transpolar flight (Nobile 1928a) or the *Italia's* prior round-trip Arctic flights. Therefore, precisely because of Nobile's effective design, it seems rather unlikely that one or more frozen valves accounted for the sudden and significant loss of lift experienced by the *Italia* after its descent back into the fog bank.

A different hypothesis for the cause of the crash, which was based on the supposed piloting decision errors performed by Nobile an hour before the crash, was suggested several years later by Dr Knut Eckener, a doctorate in engineering and the son of the famous German Zeppelin airship designer Hugo Eckener. Knut Eckener postulated that Nobile had lost a critical volume of the hydrogen lift gas when he ordered the airship to ascend above the clouds, because of a combination of gas expansion associated with the increase in altitude as well as the gas expansion due to thermal heating incurred while the airship was in direct sunlight. The gas expansion would result in off-gassing through the (non-frozen) automatic valves of gas cells, which were put in place to avoid an over-expansion and possible rupture of gas cells (Eckener 1958). This assumption, which has already been extensively described and analysed (Bendrick et al. 2016) appears theoretically possible, but Eckener's hypothesis has a weak point: He could never produce any evidence or declare the source of his information regarding the gas pressure.

In the interests of historical accuracy, it should be noted that Nobile later prevailed in a lawsuit brought against the

publishers of Eckener's technical note, along with Eckener himself, in which Nobile alleged libel resulting from disparaging remarks made in the context of Eckener's analysis (Anonymous 1961). The lawsuit also noted that Eckener had no factual basis on which to make his claim of causation for the crash. In the settlement the defendants admitted that there was no evidence to attribute the accident to either moral failure or professional incompetence on the part of Nobile. Yet although Nobile denied their applicability to the crash of the *Italia* because "no gas could have been lost automatically through the valves" (Nobile's letter dated 6 October 1958 to K. Eckener), he was forced to admit in a letter to his lawyer that Eckener's technical considerations quoted above were "quite correct" (Nobile's letter to his lawyer dated 15 March 1959). These documents of the trial (Nobile Umberto vs Putnam & Company Limited and Eckener; Statement in Open Court, High Court of Justice, Queen's Bench Division No. 535, 1959) were retrieved at CDUN ("Querela contro Eckener 1959," position XV/5, "Italia" N4).

Such a technical explanation in which the physical relationships among altitude, pressure, temperature and volume are described, remains one of the most probable to theoretically explain the sudden and dramatic loss of buoyancy leading to the crash of the *Italia*. Although one cannot say with certainty the undisputed cause of the crash, the hypothesis outlined by Eckener accounts for all facts as commonly acknowledged in the absence of verified pre-crash structural or outer shell damage.

Additionally, one crucial fact cannot be denied. Nobile chose not to restart the ship's engines immediately after the uncommanded descent had been negated and the elevator-wheel had been unjammed by Viglieri. In hindsight, this would have been the most rational choice, since he had just ordered those engines to be stopped in order to avoid the crash. Once the crash was avoided, he should have restarted the engines and proceeded accordingly. Instead, Nobile was convinced by Mariano to pilot the airship to an altitude above the cloud layer in order to fix their position, rather than pressing onwards to their destination. Although this decision may at first seem understandable, the meteorologist Malmgren had begged Nobile to get away as quickly as possible from that stormy area (Nobile 1930). Moreover, Nobile himself and chief motor engineer Arduino were very concerned that gasoline stocks were scarce, as the engines were running at full capacity (Nobile 1930; Trojani 1964). Since their navigation was still under the radio-goniometric control signal regularly sent by the support ship from their base, it is likely that fixing their position could have been used to determine their distance from Kings Bay. This bearing, combined with speed and drift data, would have allowed Nobile to

radiotelegraph the support ship their position and estimated time of arrival (Viglieri 1929: 20).

Nobile decided, however, to perform this manoeuvre, releasing the lifting gas again, as he had already done at 07:00 GMT. He was sure that the airship was “light” and so he was not concerned about reducing the amount of lift gas. Also, he released the gas only from the bags in the stern in order to balance the pressure in all compartments while the airship was still in the cloud layer. This declaration by Nobile, however, conflicts with the statements made by the three officers who told the commission that they saw him also vent gas from all compartments while above the clouds (Nobile 1945).

Flying above the cloud layer, however, entailed the risk of losing even more lift gas because of the effects of altitude and heating. The airship most likely remained in direct sunlight for approximately 20 minutes (Trojani 1964), thereby allowing solar heating to further expand the lift gas, with high chances of releasing more of the gas through automatic valving. Upon return to the relative darkness and cold of the fog bank at lower altitude, and with the subsequent contracting of gas and decrease in pressure, there was no longer enough static lift to maintain level flight. All these factors together most likely contributed to the crash of the airship.

What was argued by Eckener (1958) in his short treatise, therefore, had the merit of highlighting the fact that the manoeuvres carried out only to fix the position by Nobile were quite hazardous, especially in a long-endurance mission. This was precisely because of their effects on the hydrogen reserve available, its role in preserving static lift and, consequently, flight duration.

Many relevant issues could be the object of further study, but in the following pages one factor—that of fatigue and its underlying cause as well as its consequences in the moments preceding the crash—is the focus of greater scrutiny.

Fatigue and human performance

In the case of the *Italia*'s accident, the possible contributing factors constituted by the above-mentioned manoeuvres beg the following question: Why would an experienced airship pilot and engineer, who clearly understood the relevant principles of elementary physics, make such a series of misjudgements so as to risk the loss of a critical amount of lift gas? The answer to this question is the cognitive impairment resulting from sleep deprivation. In a separate publication the facts have been examined in more detail regarding the effects of sleep deprivation and altered circadian rhythm on human performance (Bendrick et al. 2016). But particularly in aviation, a decrease in human performance such as that seen with fatigue can

have important consequences. When piloting a vehicle through three-dimensional space, the operator(s) must be cognizant of—and react to—a constantly changing environment, and there are several factors that characterize the fatigue related decrements seen with human performance (Durmer & Dinges 2005). One is a general slowing of cognition, that is, information processing, in which there is a reversion to old, previously learned response actions that are continued even in the face of ineffective response or new information. That is, one keeps trying to do the same thing despite the fact that it is not working (Harrison & Horne 1999, 2000; Nilsson et al. 2005; Killgore et al. 2006; Alhola & Paivi 2007; Monk 2007; Venkatraman et al. 2007; Maddox et al. 2009; Horne & Moseley 2011; Libedinsky et al. 2013).

Fatigue is also characterized by impaired innovation, i.e., an inability to develop creative solutions to perceived problems as well as a reduced ability to manage unexpected information and/or information from multiple sources. There is a reduced ability to understand the risk differences among various options, and an increasing tolerance of risk. Together, these decrements often result in poor decision-making. Likewise, there is reduced and/or impaired communication among operators (Durmer & Dinges 2005), which results in a reduced ability to form and maintain situation awareness. Precisely because of these effects on performance, fatigue has been identified as a causal or contributory factor in several major aircraft accidents (National Transportation Safety Board 1994; Goode 2003; Gokhale 2010). For a more complete review of the psychological and cognitive effects of sleep deprivation, circadian dysrhythmia and fatigue in the context of the *Italia*, the reader is referred to a prior publication on the subject (Bendrick et al. 2016). Likewise, the interested reader is referred to a more exhaustive discussion specifically discussing the issue of human fatigue in aviation (Caldwell & Caldwell 2016).

Nobile's sleep-wake cycles can be estimated from a close reading of his memoirs. It appears that he himself had been awake for over 72 hours at the time of the crash. In the previous publication the authors argue that Nobile made at least three command-related errors leading to a loss of static lift, all of which were of types associated with the extreme cognitive impairment predicted for an individual who had been awake for 72 hours or more (Bendrick et al. 2016).

In Nobile's writings there is the implication that the avoidance of sleep was an admirable trait that was to be expected of a good leader and that with enough will power and discipline a person such as himself could overcome or at least delay the effects of sleep deprivation until there was an opportune time for recovery. Ignoring the desire for sleep appeared to be Nobile's standard practice

on such missions. For instance, on his expedition of the *Norge*, upon landing after one of the initial staging flights he notes the following:

I was exhausted. For 60 hours I had been awake, without closing my eyes for a moment: good training, indeed, for the Polar flight! ... I could barely stand ... An hour later, in one of the salons of the palace, I could barely summon up strength to murmur a few words of thanks in reply to the addresses of welcome from the Agent of Foreign Affairs and the doyen of the professors. Immediately afterwards I dropped into bed in the room they had assigned to me. (Nobile 1961: 40)

Later, when describing the latter part of the *Norge* flight over the North Pole he writes as follows:

So once again I had to take over the elevator wheel, replacing Wisting, who was so tired that at times I saw him unconsciously closing his eyes ... I was very tired: I had not had a single moment to sit down and rest; there were times when I felt I could bear it no longer. I realized that my instinct of self-preservation had vanished; if my own life had been the only one at stake, I would have let my eyes close in irresistible sleep. But the sense of responsibility was strong, and I could still find—I don't know how—strength to resist my physical exhaustion and stay glued to my post, with my eyes open and my mind alert, in a supreme effort of will-power. (Nobile 1961: 76)

And expanding this window into his character, he adds later:

By this stage of the flight, having slept [for] only 3 hours out of the preceding 97, I was thoroughly exhausted; yet from somewhere I drew sufficient reserve of strength to make a landing... (Nobile 1961: 94)

In the context of these comments, Nobile obviously did not realize how one's own feeling of alertness can be deceiving in such circumstances. In other words, if one's brain is compromised by fatigue in its judgment-making ability, then that person is not an appropriate individual to gauge his or her own level of fatigue or performance. In Nobile's case, just prior to the mishap sequence that brought down the *Italia*, and after having been continuously awake for nearly three days straight, he notes: "It was a really difficult situation. But—as always in similar circumstances—the difficulties had excited my energy: I did not feel tired, but even more alert than usual" (Nobile 1961: 151).

Another important confirmation comes from the memoirs published in 1930 by Professor Běhounek, the illustrious Czech scientist who survived the *Italia* expedition.

He emphasized the following (while at the same time demonstrating his admiration for Nobile's qualities):

Nobile rested less than everyone. The exemplary commander, he was always in his place in the cockpit, constantly watching the helmsmen and the navigation works, allowing the entire crew the greatest possible rest, sending the officers to sleep and patiently watching himself ... Always standing, he did not allow himself a minute's rest. (Běhounek 1930: 49; authors' translation)

Finally, there is a note, written by the hand of Nobile himself that leaves no doubt as to the degree of his own sleep deprivation: "In the two expeditions I remained in my command post 457 hours, during which I rested less than three hours on the whole!" (retrieved at CDUN, position XV/12, "Italia" N4; authors' translation).

The neurocognitive impairment of someone who has been sleep-deprived for that period of time is well described (Doran et al. 2001; Durmer & Dinges 2005). As already noted, it has been proposed that Nobile made various decisional misjudgements in the mishap sequence, and all are consistent with insufficient sleep. With the benefit of hindsight, those manoeuvres can be qualified as imprudent for not having sufficiently assessed the possible harmful consequences. As detailed in both report of the Commission of Inquiry and Eckener's account, these manoeuvres constituted an unjustifiable risk that endangered the airship, which was also worn out after many hours of difficult navigation. One would certainly not expect a commander with Nobile's experience to make mistakes of this sort normally. Yet the reason why an airship pilot would make the sequential and relatively elementary mistakes that likely contributed to this mishap is precisely the commander's fatigue, resulting from sleep deprivation and its effect on neurocognitive performance.

Additional elements reinforce this statement, as can be inferred from the examination of a specific order given by the commander when the airship suddenly began its final descent. Nobile at that time was able to think of only a single cause for the problem: that the gas valves of the stern compartments, opened during the climb above the clouds layer, had become stuck in the open position because of ice formation on their seats. He therefore ordered rigger Alessandrini to go to the top of the airship to check automatic valves. However, the rate of speed of the airship's descent gave Alessandrini no time to execute the order (Nobile 1969). In fact, this order was given at nearly the last point in the mishap sequence, just before the engines were stopped, when, in the words of an eyewitness, "the end was a matter of seconds" (Viglieri 1929: 21; authors' translation). The airship had already begun its unstoppable

descent, inclined at approximately 30°–40°, and practically did not respond to any input anymore (Biagi 1929; Viglieri 1929; Běhounek 1930; Trojani 1964). The control of valves a few tens of metres from the inevitable impact against the pack ice could not have brought any advantage, because there was not sufficient time to intervene. Yet, in his compromised state of mind, that was the only thing Nobile could surmise as the possible cause of the critical loss of static lift, rendering further proof that he did not fully comprehend the consequences of his orders. These patterns of thought are characteristic of a sleep-deprived individual exhibiting the deterioration of performance requiring divergent thinking (i.e., problems requiring the evaluation of multiple potential solutions) and persevering with ineffective solutions (i.e., keep trying to perform an action even when it is not producing the desired result). In short, Nobile was no longer able to develop any new solutions to the problem of rapid descent.

Furthermore, just prior to the crash Nobile appropriately ordered the engines to be stopped to avoid catching fire on impact. Yet in this extreme situation he also acted surprisingly, as the crew members saw him (and Mariano) shouting from the control gondola window to motorist Caratti, whose engine was slowest to stop. Nobile (1945: 244; authors' translation) himself reported the event in these terms: "When he realized that the left engine had not notified the order, he had to lean out the window to repeat it loudly until he saw the propeller stop." However, one wonders how the motorist could have heard a scream shouted in the wind, 26 m away, while seated next to a roaring motor, close to the engine in a metallic "nutshell" (Trojani 1964: 754). Obviously, the motorist did not hear any shouting; he could only receive, as he did, the order transmitted by the proper means installed on board for that purpose (called the "telegraph"). The three motorists had always acted promptly to the commands given to them previously. Thus, the fact that Nobile shouted from the window to the distant and inaccessible crew member Caratti was another example of a cognitive effect of sleep loss—namely, the reduced ability to deal with the unexpected.

Other circumstances demonstrate this specific condition, which undoubtedly had serious and appreciable consequences even later in the fall of the airship, delaying rescue operations. In the final moments of the fall the rudder operators were changed, affecting both the direction and the elevator (MM 1930). Cecioni was sent to throw off the chain of balls, the heaviest ballast on board being of 400 kg (Viglieri 1929). However, he failed; no one was ordered to help the chief technician perform that vital manoeuvre, which would greatly dampen the momentum of the fall. Only the Czech scientist, following only his impulse, tried to help him (Běhounek 1930).

Another serious problem was that of having allowed the presence of only a single radiotelegraph operator on board, a clear violation of the safety rules and precautionary criteria. There had been two of them on the *Norge* expedition (Amundsen & Ellsworth 1927). Moreover, instead of launching an SOS this single operator was engaged in the launch of ballast (Biagi 1929) and saving the radio antenna (Viglieri 1929) and, as a consequence, the airship's last position before the crash remained unknown. This circumstance was also confirmed by witnesses aboard the support ship, which could have organized the rescue operations far more quickly and effectively if the airship coordinates had been known a few minutes before the mishap (Tomaselli 1929).

These facts, in addition to demonstrating serious problems of communication, crew coordination and leadership in the cockpit, may also indicate that everyone—especially the commander—was so fatigued after a 54-hour flight that they realized the airship was about to crash only in the final moments of the crisis.

Underlying cause: no SIC

The more intriguing question, and a root cause underlying the excessive sleep loss, is why did Nobile not have a deputy commander, formally known as the "second-in-command" (SIC)? Such an individual would have been able to relieve the commander temporarily of his duties, giving him a chance to acquire needed rest. An SIC was an official and formally certificated position, something more than simply the second-ranking person on the airship, and to designate such a position was a standard practice of the time for seafaring vessels as well as airships. For instance, several years prior to the voyage of the *Italia*, Nobile himself noted that a designated SIC would be a necessary crew position for an airship, as he stated in two papers both available as *Technical Notes* in the archive of the American National Advisory Committee for Aeronautics (Nobile 1921a, b). This committee, which began in 1915, was the precursor to the National Aeronautics and Space Administration, formed in 1958. *Technical Notes* were the basic unit of the research report series (Nelson 1999). Some early *Technical Notes* were translations of foreign works, such as those of Nobile reported here, both published in 1921. In these papers Nobile describes the properties of airships, annotating their minimally required supplies and crew in an effort to estimate weight and, therefore, cost of operation. In the first of these *Technical Notes* he states:

The minimum crew needed consists of
 1 Commander
 1 Pilot

1 Mechanic

1 Wireless operator.

With increased cubature of the airship, we may, generally speaking, assume that the journeys undertaken will be longer and more fatiguing, and that, therefore, double shifts will have to be provided for. (Nobile 1921a: 12)

He clearly sees the necessity of having both a commander and a pilot, who could act as an SIC to allow the commander a period of rest and sleep on the lengthy flights of which an airship would be capable. Nobile even foresees the need to cover double shifts, since the flight times for airships would exceed the capability of a single individual to remain awake and functional for the duration of the mission. The implication here clearly is the need for an SIC.

Similarly, in the second of these two *Technical Notes*, in the midst of a long discourse assessing the potential weight, lift, size and cost of airships, he lists again the minimum requirements for the airship's personnel:

Navigating Personnel.

Each crew would consist of the following: 1 Commander; 1 Second Commander; 2 Steersmen; 1 Chief Motorist; 3 Motorists; 1 Radio Operator; 1 Laborer; 1 Rigger; 1 Mechanic, totalling 12 persons. (Nobile 1921b: 29)

Here he specifically delineates the need for a "Second Commander" in the context of a larger airship with a potential for even longer flight. At the time of writing these papers Nobile clearly recognized the need for an SIC to relieve the commander throughout the extended flights of an airship. This necessity was recognized even in the face of the costs of the weight of an extra crew member, and the impact that would have on the overall amount of cargo or number of passengers an airship would be able to carry for revenue-generating purposes.

But by the time of the *Norge* expedition in 1926, Nobile's thoughts on having an SIC had seemingly changed. While discussing his selection of crew members for the *Norge* Nobile broaches the idea of having a deputy who could take over the duties of piloting the dirigible in order to give himself some time for sleep. Then he dismisses the thought:

Certainly, the pressure of another expert pilot would have enabled me to rest from time to time, sparing me an uninterrupted vigil of 32 hours ... But, all things considered, I do not regret it. When responsibility is concentrated in a single person ... his attention is sharpened, his decisions are made swiftly and swiftly carried into effect. (Nobile 1961: 23)

Presumably, because the experience of flying the *Norge* over the North Pole in 1926 was a success, Nobile later felt justified in not having an SIC for the *Italia* expedition. The question is why, when just a few years earlier Nobile had clearly pointed out the necessity of having a "Second Commander" to act as SIC, he would then find such a position unnecessary when preparing the flight of the *Norge*, setting the stage for a similar decision in the case of the *Italia*?

The *Norge*'s SIC

One explanation is that Nobile's role on the *Norge* was not actually that of a commander of the expedition. On the *Norge* he himself was the pilot (i.e., the captain) of the airship, as established by a royal decree and stated per contractual agreement. Roald Amundsen, along with Lincoln Ellsworth, was the co-commanders of the expedition: Amundsen had come up with the idea and Ellsworth had funded it. Yet the arrangement was a bit more complicated. The contracts signed by the Italian crew members specified that on board they would be dependent exclusively on the Italian officer in command of the airship (i.e., Nobile), to whom they had to "obey unconditionally" on their honour. But while on the ground, both before and after the flight phases, and in any case "for everything that does not refer to the airship," they would have to obey unconditionally the head of the expedition (i.e., Amundsen) and declare themselves "ready to do any kind of work was required for the success of the expedition" (Alessandrini 2019). Adding confusion to the issue, in a statement shortly after the *Norge* expedition, published on 20 July 1926, Nobile states, "Riiser-Larsen, second in command of the airship, was appointed navigator by me" (Anonymous 1926: 1).

Notwithstanding any confusion by others on the topic, Amundsen considered Nobile to be a hired pilot of the airship, but neither the commander nor an SIC. Amundsen is quite unambiguous on this matter:

I ... emphatically pointed out to Nobile in plain terms that he was nothing but a hired pilot... On an exploring expedition, where the vessel shall go is absolutely within the province of the commander. He defines the objectives, and the captain of the vessel carries the commander's orders into effect by so ordering the management of the ship as to make it proceed safely to the point designated by the commander. It was this sharp distinction between the functions of the skipper of the N-1 and the commanders of the Polar expedition—Nobile being the former and myself and Ellsworth the latter—which

Nobile either could not, or would not, get into his head. (Amundsen 1927a: 158–159)

Amundsen reiterates this point later when he recounts a conversation he had with Nobile:

I pointed out that the expedition was not an official undertaking of any government, but was a private enterprise originated by Ellsworth and myself. Nobile had been employed to accompany it, not as an Italian officer, not as a representative of the Italian government, but as a private individual who happened, by reason of his familiarity with the dirigible, to be the most available man we could employ in the important but subordinate position of skipper of the ship. (Amundsen 1927a: 205)

Moreover, in the appendix to Amundsen's memoirs, Riiser-Larsen (1927), who held the rank of captain in the Norwegian Navy Flying Corps, clearly states that he himself was the official SIC of the *Norge* expedition, a fact ironically acknowledged later by Nobile (1961) himself. The reason that Nobile did not pick another pilot, or SIC, for the *Norge* expedition was because one was not needed: the *Norge* in fact already had an SIC and this was Hjalmar Riiser-Larsen. This arrangement may have underlain Nobile's confusion on the subject. Given the totality of the evidence, it appears that Nobile was third in the top-three chain of command, providing at least two layers of command oversight that could correct any situation that might develop should Nobile make an obvious error in his duties.

This is in fact what happened, and not just once. Amundsen relates no less than three different instances throughout that expedition in which Nobile appeared to have been experiencing significant cognitive impairment while piloting the *Norge*. The first instance Amundsen describes as follows:

The nose of the *Norge* responded and tilted downward toward the ice. As I was facing forward, I could see that we were getting closer and closer to the surface. I looked at Nobile and he seemed not to realize what was going on. He seemed, indeed, to be standing in a sort of daze ... The ship was speeding swiftly toward the rough ice below us. Another moment, and we should be dashed to pieces. Riiser-Larsen sensed the danger. Nobile seemed insensible to it: he stood like a man in a trance. Riiser-Larsen sprang to the wheel himself, thrust Nobile roughly to one side, and himself spun the wheel around. (Amundsen 1927a: 177–178)

From Amundsen's description of this episode it seems as if Nobile were experiencing something that sleep

scientists call "micro-sleep," which are brief periods in which the brain enters a state of full sleep, even if the individual's eyes are open and he is performing a routine task (Durmer & Dinges 2005). Micro-sleeps typically begin to occur after sustained wakefulness of 24 hours or more, and/or when there is significant sleep restriction over several days. They generally occur without warning, that is, there is no progressive sense of drowsiness before the incident occurs. Micro-sleeps can be particularly dangerous for operators of vehicles or vessels that are in motion as the person experiencing the micro-sleep does not even realize it has occurred, making it unlikely that he or she would take any mitigating actions against it. It is worth noting that Nobile himself states that at this stage of the flight in the *Norge* he had had only three hours of sleep in the preceding 97 hours (Nobile 1961). Moreover, Nobile's own memoirs attempt to further clarify this particular episode by stating the following (referring specifically to Amundsen's comments):

Here once more he has failed to realize that Riiser-Larsen and I were acting in concert. We were flying almost at ground level under thick fog over a very hilly country. In such conditions the handling of the elevator had become very difficult, and as no Norwegian was sufficiently expert I had to take the wheel myself, watching the ground and quickly maneuvering in order to avoid collisions. But from where I stood the vision of the ground was not clear enough; therefore I stationed Riiser-Larsen at a porthole to warn me of obstacles. Each time he saw the ground rising through the fog, he was to shout "Up!," reinforcing the warning when necessary with a gesture of his hand toward the elevator. (Nobile 1961: 94)

It is interesting to note here that Nobile does not specifically address Amundsen's statement that Nobile was "insensible" and as if "in a trance" (Amundsen 1927a: 178), which, if true, strongly suggests micro-sleep. This omission implies that Nobile may not have remembered that particular detail, a fact that would be consistent with experiencing micro-sleep.

This episode was apparently not the only one in which Nobile seems to have experienced micro-sleep. In another instance Amundsen states the following:

Exactly this same incident happened a second time on the voyage, but with one variation. Again Riiser-Larsen saw us about to crash into the ice. This time he shouted a rough command of warning to Nobile to change our elevation. Nobile gave a start like a man coming out of a dream. (Amundsen 1927a: 178)

In a third instance Amundsen describes events as follows:

The third incident was this ... Nobile at once did the only thing to do. He spun the wheel of the vertical control so as to point us upward in an effort to climb above the fog bank. He was in such nervous haste to do this, however, that he gave no thought to the gas pressure in the bag. We mounted swiftly to a high altitude. Suddenly Nobile "came to." We had reached a point so high as to reduce the atmospheric pressure on the outside of the gas bag to a point where the gas pressure inside threatened to burst the bag. (Amundsen 1927a: 178–179)

Riiser-Larsen provides a second witness to the account described by Amundsen:

On two occasions when the ship's bow rose a bit Nobile gave rudder to get it down again, but apparently forgot that he had done so and furthermore apparently forgot that he was at the wheel. We were just above the ice and undoubtedly would have collided with the hummocks if nobody else had watched him and taken the rudder before it was too late ... On a third occasion when he was acting as pilot (when he slept I was in charge of the ship) when we were ascending to get above the clouds in order to get an observation of the sun, he forgot to watch the gas-pressure. When he at last observed it, it had risen to such height that both he and we thought the envelope would burst. (Riiser-Larsen 1927: 272–273)

Riiser-Larsen concludes his assessment succinctly: "Had Nobile had his way we would have probably been lost" (Riiser-Larsen 1927: 277). In other words, had Riiser-Larsen not been the SIC, Nobile's performance (presumably due to sleep-deprived cognitive impairment) would have led to a crash of the *Norge*. Nobile also described this episode, but in a different way, giving emphasis to how he succeeded in taking control of the airship again and managed to pilot her to a lower altitude (Nobile 1961). In any event, everyone agreed on the extreme danger of the incident, perhaps one of the worst risks that an airship could take during a flight.

Some of these observations were originally made by Amundsen in August 1927 in the periodical *The World's Work* (Amundsen 1927b). Nobile responded in January 1928 in that same periodical, noting that the two instances described by Amundsen in which they descended rapidly and nearly crashed onto the ice were "cause for laughter" (Nobile 1928b). These same observations, along with others made by both Amundsen and Riiser-Larsen, were

later published in 1927 in Amundsen's memoir, *My life as an explorer*, which came out before the flight and crash of the *Italia*. In his memoir, Amundsen (and Riiser-Larsen) made several other disparaging remarks about Nobile and his actions regarding the flight of the *Norge*. Indeed, the relationship between Amundsen and Nobile had been problematic since the very beginning. When the *Norge* expedition ended with great success, Nobile had become a useful propaganda tool for the fascist regime, and that fact made their relationship even worse, because Nobile's association with the fascists was a major provocation to Amundsen that eventually resulted in open conflict (Aas 2003). On this basis, one can explain the very negative and little objective considerations that Amundsen made on Nobile in his 1927 autobiography. While there is merit to some of Amundsen's observations, and while there may also have been other incentives in describing personal conflict during the famed expedition—selling more books being among them—it should be noted that Nobile had not read Amundsen's memoir until after the *Italia* expedition and crash (Nobile 1961). It was not until Nobile published his own memoirs in 1961 that he directly addressed many of the points of contention raised by Amundsen. In this context, Nobile summarizes his sentiments as follows:

The accusations in themselves are self-contradictory and absurd, but on account of the name of their author they might be perpetuated. To avert that risk I have thought it necessary to tell the facts exactly as they happened. This is all the more painful to me, since I had hoped that the whole trivial, bitter wrangle would have been washed from the world's memory, as it had been from mine, when the waters of the Barents Sea closed over Amundsen, as with a generous impulse he himself put it all behind him and flew to the help of the *Italia* castaways. (Nobile 1961: 95–96)

It is still worthwhile to note that except in a general, dismissive way described above, Nobile did not challenge or contradict the specific observations made by Amundsen and Riiser-Larsen with regard to piloting the airship. He did not specifically challenge the descriptions of what we would now suspect to be episodes of micro-sleep; on the contrary, he actually confirms the assistance of Riiser-Larsen in piloting the airship. In these instances it is evident that Riiser-Larsen interacted with Nobile in a way that only one of equal or higher rank (i.e., SIC) could do. It is extremely doubtful that the actions performed by Riiser-Larsen—for instance, he "sprang to the wheel himself, thrust Nobile roughly to one side, and himself spun the wheel around" (Amundsen 1927a: 178)—would

have or could have been performed by someone who was of lesser rank and not fulfilling the specific role of an SIC.

In addition to this, Nobile himself may even have underestimated the amount of sleep he obtained on the flight of the *Norge*. He does make it a point to note that prior to take-off he remained awake all night, waiting for weather to improve, after he had worked the entire day prior making the final preparations for that flight (Nobile 1928b). Regarding the time on the *Norge*, he noted at one point that he had “slept only 3 hr out of the preceding 97” before its landing (Nobile 1961: 94), and in another passage he noted that after landing the *Norge* he had been awake for 60 hours “without closing my eyes for a moment” (Nobile 1961: 40). Likewise, there is a note, written by the hand of Nobile himself in which he estimates about the three hours of rest with respect to 457 hours at his command post, as was previously mentioned. However, if the observations of Amundsen and Riiser-Larsen are accurate, this may be an underestimate of his actual sleep time during the flight. Amundsen notes that Nobile took naps:

I must at this point take notice also of some of the absurd stories that have been circulated in the Italian press since the flight. For one thing, those papers have declared that the Italians did all the work while the Norwegian members of the expedition slept. The truth is that, though no one on board did more than snatch a few hours of uneasy slumber now and then, the one member of the expedition who slept by far the most was Nobile himself. (Amundsen 1927a: 180–181)

The accuracy of this particular observation is subject to question, but Riiser-Larsen had some more specific comments on Nobile’s sleep patterns:

If we add the hours he rested he probably had slept in his sleeping bag for more than six hours when we came over land on the Alaska side. From then on he slept until we had passed Cape Lisbourne, and later he slept between Serpentine River and Cape Prince of Wales, which was quite a while as we made very slow progress on account of the storm ... I am quite sure that Nobile in all slept for more than ten hours. There were not more than two or three on board who had that much sleep. (Riiser-Larsen 1927: 274–275)

If one accepts Riiser-Larsen’s account, Nobile had more sleep than the three hours out of 97 hours that he himself had estimated. And even though it may have been closer to 10 hours of sleep, as Riiser-Larsen estimated, this is still an evidence of significant sleep restriction on the part of Nobile throughout the flight of the *Norge* and that it was

severe enough to lead to the suspected episodes of micro-sleep described earlier.

On the basis of these collective statements one may conclude that Nobile underestimated the total amount of sleep he obtained during his flight on the *Norge*, while at the same time overestimating his level of performance while sleep-deprived. In retrospect, it is therefore clear that his assessment was inaccurate. For example, when Nobile (1961: 23) stated, “When responsibility is concentrated in a single person ... his attention is sharpened, his decisions are made swiftly and swiftly carried into effect,” he is in fact mistaken regarding his judgement of his own performance. If one is to give any credence to Amundsen’s and Riiser-Larsen’s accounts, Nobile’s attention and performance were not sharpened but instead seriously degraded at times, despite the responsibility for the control of the airship being concentrated at that time in a single person.

The *Italia*: no SIC

Nobile nonetheless decided to do without an SIC for the *Italia* flights, based on his own assessment of his performance (albeit inaccurate), and the overall success of the *Norge* expedition. Nobile discusses this decision deliberately and in some detail in his writings. It was while still recovering from the *Norge* flight that Nobile conceived the idea of a new expedition. He discussed it with Riiser-Larsen, noting that, “The expedition would be called the Nobile–Riiser-Larsen, and would fly the Italian flag” (Riiser-Larsen 1927: 277; Nobile 1961: 100). Riiser-Larsen was presumably in line to be the SIC of the airship, this time under the undisputed command of Nobile. Nobile (1961: 100) went on to state: “We promised each other that we would discuss it further. But we never did, because of the misunderstandings that I have just described.”

In his 1931 memoir, Nobile mentions the fact that he also endeavoured to secure the service of the Norwegian Oscar Wisting, an experienced Arctic explorer and close associate of Amundsen, who had been on the crew of the *Norge*. Nobile describes his attempt as follows:

Obliged definitely to give up any idea of collaborating with Riiser-Larsen ... I thought of securing the collaboration of Wisting, who, with his vast experience of the Arctic and his sterling qualities, would certainly have proved an ideal companion. I met him one day in the streets of Nome, and spoke to him of this. He declared that he would very willingly take part in the new expedition ... but later he was unfortunately prevented by other engagements from joining me. (Nobile 1931: 24)

After that account Nobile goes on to describe his effort at securing the hangar at Kings Bay and does not mention again the prospect of an SIC for the *Italia*.

In his 1961 memoir Nobile does discuss in some detail his choice of various crew members for the expedition. Regarding other officers, he states:

For the two navigating officers I applied to the Admiralty who particularly recommended Commanders Mariano and Zappi. Both of them, but more especially Zappi, had some experience of airships ... At the same time the Admiralty sent me two other officers to choose from, and one of them—Viglieri—particularly pleased me. After I had inquired into his previous record I asked to have him too, meaning to use him either to man the steering-wheel or to help with the navigation ... Finally, I chose Trojani, to take turns with Cecioni at the elevator-wheel. (Nobile 1961: 104–105)

According to Mariano's subsequent testimony to the Commission of Inquiry (MM 1930), he had explicitly requested the position of SIC from Nobile but was declined. Moreover, Commander Zappi was assigned as the second officer, but not the SIC, although he was the one who surely held the military patent (i.e., certificate) of Dirigible Pilot Qualified to Command an Airship (achieved in October 1917, as attested by a Royal Navy certificate signed by the commander of Italian Royal Navy aerodrome of the city of Jesi, dated 25 January 1919, and now exhibited at the North Pole Expedition Museum of Long year byen, Svalbard). Thus, Zappi in fact could have been appointed an SIC. But although he held the licence, and even though Nobile knew his qualifications very well, Nobile considered it inappropriate to assign him this role because Zappi as a Naval officer was junior in rank to Mariano. According to Nobile this rank disparity would have been an insurmountable obstacle to assigning such responsibility (Nobile 1945). In a later account Nobile clarifies his reasoning as follows:

With this, my problem of having an experienced dirigibilist to whom I could entrust the duties of second commander was not, however, solved, because, among the officers of Marina, the only one who had such a patent was Zappi. But Zappi as an officer was less senior than Mariano, and therefore I could not put him under his control. To avoid difficulties, I decided not to formally have a second commander, and I appointed Mariano as first officer on board. (Nobile 1969: 140–141; authors' translation)

According to this statement, Nobile did not choose Zappi as the SIC because of the "difficulties" that would ensue with rank-inversion between Mariano and Zappi.

In short, Mariano, as the first officer, would answer to Nobile, but would never replace him during any of the *Italia* flights, not even for a period of rest by the commander. Zappi would be available only to relieve Mariano when necessary.

It is here worth noting a passage from the memoirs of crew member Trojani, in which he recounts a conversation between himself, Zappi and Mariano in front of the hangar entrance at Kings Bay one of the days before the airship's final flight:

Zappi called me, and after a long preamble told me that Nobile had charged himself with too many responsibilities, that in the last flight he had shown himself very tired, that in order to lighten the fatigue it was necessary to appoint a second-in-command, and that the second-in-command had to be Mariano. Mariano was silent. I was not surprised by that decision: I expected it ... But was a second-in-command actually necessary? There were only a few of us working in direct contact; would an intermediary between Nobile be useful? Would it actually work? Undoubtedly, Nobile would continue taking the same responsibilities and taking on too much work.

Not having established a rigid hierarchical ladder among the crew members was perhaps deplorable in theory, but actually it was not causing any disadvantages: we were all under one chief and knew what our duties were. Our relationship was governed by logic and good manners, and we worked in perfect harmony. Anyway, would Mariano's choice be the best choice? As a navigating officer he didn't look cleverer than Zappi and Viglieri, his aeronautical practice was more boasted than actual; he had no Arctic experience, no technical knowledge of the airship ... If a second commander had to be there, it should be chosen either among experts and authentic airship pilots, or among experts and authentic polar explorers. (Trojani 1964: 312–313; authors' translation)

In this recollection, Trojani hints at the apparent ambition of Mariano in being named the SIC, and if this were true, the fact certainly would not have been lost on Nobile. Precisely because of the lack of experience pointed out by Trojani, Nobile perhaps chose not to have Mariano as the SIC. Moreover, Trojani notes that having an SIC in a strict hierarchical chain of command would have been counter-productive, though he obviously ignores the fact that an SIC could have provided periods of rest to the commander on an extended flight.

To what extent personal ambition or lack of experience may have played into Nobile's decision ultimately to have no SIC is unknown, but the scenario does point

out the fact that there were many factors affecting this decision. In the end, according to Nobile, it was a matter of seniority in service, and personal skills or qualifications did not figure into the decision. But Nobile's argument is poor and unconvincing, and may be better viewed as a pretext for a decision already made. That is because Nobile and the other crew members, including the officers, were not carrying out a military activity. They were not dispatched on a military expedition, but rather a civilian one with relevant scientific research objectives. The dirigible itself had been transferred to the Royal Italian Geographical Society, which had to pay compensation to the Ministry of Aeronautics in the form of insurance valued at 2.7 million lire. All the crew members had entered into a contract with the civilian institution because they were on a "royal service mission." For this reason their respective military administrations had put them on leave from the Italian corps to which they belonged, as was established in the special convention drafted between Aeronautics and the RSGI on 6 December 1927 (Alessandrini 2019). Once transferred, the airship was to be considered a civilian airship, as was admitted by Balbo himself during the inquiry.

Maybe Nobile simply did not consider Zappi adequate for the task; perhaps he felt Zappi lacked flight experience in the Arctic, or perhaps he had some other personal consideration. In any case, the apparent inappropriateness of having Zappi as the SIC, and the deliberate choice to not select Mariano for the task, resulted in deployment of the *Italia* on its missions without an SIC.

Nobile later claimed that his decision not to take an SIC on the flight of the *Italia* was not a deliberate one, and it had not been his choice. Rather, he was forced to renounce appointing an SIC because the Regia Aeronautica dirigibilists would not be granted permission to participate (Nobile 1969). Although there has been no official record uncovered to date to substantially support Nobile's claim on this matter, there are nevertheless some reliable clues that support his position. For example, Major Pio Revello (then commander of the aerodrome of Pontedera, near Pisa) declared that he had been summoned to Rome by Nobile who proposed him to participate in the expedition as a pilot. Revello accepted with enthusiasm and remained in Rome awaiting the assignment. But when he went to the Ministry of Aeronautica cabinet, he was told that the authorization would not be granted to him ("Comandante Revello, dichiarazione del 5/1/1961," retrieved at CDUN, position IX/8, "Italia" N4, 1928). Similarly, in his statements before the Commission of Inquiry, Balbo testified that General Nobile would have required two officers of the Regia Aeronautica—Commanders Paonessa and Ilari, both famous dirigibilists—to be part of the crew. One of the two would have made it, but on one condition: To command the

airship or be a second commander; this officer, having received an unsatisfactory answer, eventually declined. The entire episode, in the words of Balbo "shows how the crew did not have definite duties" (deposition of Italo Balbo, session of 13 November 1928, CDUN, position XIII/18, "Italia" N4, 1928; authors' translation). It also shows that this unnamed Regia Aeronautica officer, who would have taken the assignment had he been appointed as commander (which was not feasible) or SIC apparently chose to renounce the invitation because he received an unsatisfactory answer. One is left to assume that the unsatisfactory answer came from Nobile, who probably wanted to avoid having at his side an officer under the control of Balbo.

Nobile's decision was also made in the context of some of the character traits he himself thought he possessed, and which may explain why he felt he could simply do without an SIC. During the selection process for the *Norge*, for example, Nobile described the specific characteristics he was looking for in his crew members:

They must also possess the necessary physical and mental qualities to stand up to the discomforts, risks and unknown factors of our voyage. They must be hardened against fatigue, indifferent to danger, calm, resolute, and at the same time enthusiastic about the enterprise. I must have the most complete confidence in them and they in turn must have the blindest faith in me, who had prepared the flight and would now have to lead it. (Nobile 1961:25)

It is fair to assume that Nobile was looking for those same qualities in his crew members when he was making his selections for the *Italia*, and it is fair also to assume that he saw in himself the very qualities he looked for in others. Perhaps he felt he possessed these qualities to an even greater extent than others. After all, if he was to be their leader, he should be the one to exemplify such qualities. It seems to be in this context that Nobile, probably turning need into virtue, decided that he himself could handle the role of commander of the *Italia* without an SIC.

In defence of Nobile's actions, one might make the argument that he chose to forego a deputy to avoid the physical weight of an additional crew member. That is, with less weight of crew Nobile could carry more emergency supplies that could be used in the event of contingency, and these very supplies indeed later proved critical for their survival. Likewise, an airship is not a Navy seafaring vessel, which arguably has much less rigorous concerns regarding weight, and an expedition to the North Pole in an airship was a new endeavour for which established rules had yet to be written. Nobile could perhaps be afforded some latitude in deciding matters of airship weight.

Yet Nobile's own statements contradict this line of reasoning. When they were at the forward operating base of Kings Bay and about to set out on the flight to the Pole, Nobile discussed his selection of the crew for that particular flight:

The crew were to be the same as before, with one wireless operator instead of two ... As for the Naval officers, I could at need have reduced the number by leaving out Viglieri, whose presence on board, though extremely useful, was not indispensable. But I reserved my decision until the last moment, making it conditional upon the available lift. ... On the field ... I had one final weighing-up, and found that it was possible to take Viglieri. (Nobile 1961: 140–141)

So, if Nobile could take a crew member whose presence for the flight to the Pole was not absolutely necessary, then he surely could have taken an SIC instead, whose presence was arguably more necessary. He simply chose not to do so.

Ironically, despite an apparent disregard for the limits of his own endurance, Nobile was inclined to bring on additional staff in order to allow other critical crew members to rest. With regard to the engine mechanics, Nobile states as follows:

With Arduino, a chief motor engineer of great merit, and Caratti and Pomella, exceptionally able mechanics, the engines would undoubtedly be looked after in the best possible manner. It was only necessary to add a fourth man to allow adequate rest during our flights to this very important part of the crew. (Nobile 1961: 103)

Nobile goes on to describe in detail the list of other officers, petty officers and technicians for the *Italia* expedition, and the respective roles they filled. He selected 18 individuals in all, including three scientists, two journalists and himself.

Appointment of an SIC for airships was already a standard practice of the time, as evidenced by the reference to such by both Amundsen and Riiser-Larsen in Amundsen's (1927a) memoir and attested by the official account on the *Norge* expedition (Amundsen & Ellsworth 1927). Whatever the reasons may be, in the end Nobile chose to proceed on the mission of the *Italia* without an SIC. He obviously made such a decision presumably based on his own perceived level of performance despite a lack of sleep on the successful flight of the *Norge*.

However, as has been shown, Nobile's performance was not as good as he thought it was, he had in fact slept more than he had estimated, and one critical reason for the success of the *Norge* flight was the very fact that there was an

SIC—Riiser-Larsen—who could literally push Nobile out of the way and take over command of the airship when needed. Nobile either did not realize these facts, or he chose to ignore them. He probably recognized the value of having an SIC when he posited the idea to Riiser-Larsen after the flight of the *Norge*. And when Riiser-Larsen declined, he still proposed the position to Oscar Wisting, who was also unavailable. Since the Regia Aeronautica dirigibilists would not be granted permission to participate, and since there were perceived problems with rank disparity of the Navy officers assigned to the expedition, Nobile decided to proceed without an SIC. As a direct result of this decision he experienced a significant degree of sleep deprivation and a significant deterioration in his performance. He then made various command decisions in relatively close sequence that may have led directly to a loss of critical lift gas (or at least caused them to stay longer than necessary in an area that they should have left as soon as possible, according to the meteorologist on board). As a matter of historical fact, there was nobody else on the *Italia* who was in a position to question or correct these orders before the *Italia* crashed onto the ice.

Human factors analysis

A possible structural failure of the envelope and gas bags could have been aggravated by manoeuvres ordered by the commander, who was seriously sleep-deprived. These manoeuvres caused unnecessary structural stresses and increased the fatigue of the crew, who were in their third polar flight in less than 20 days, and had already endured 54 hours of uninterrupted flight, much of it in adverse weather conditions.

As has been noted, an official investigation was conducted on the basis of existing documents and witnesses by various leading figures, including the survivors. The conclusions of the inquiry (made in February 1929) attributed the responsibility for the accident exclusively to the commander, accused of incorrect manoeuvring in the last phase immediately preceding the impact against the sea ice. His error fundamentally consisted in not having been able to keep the bow of the airship in the wind, which directly led to the disaster. Other charges concerned the inadequate selection and managing of the crew. The commission had an easy job assigning responsibility to General Nobile, who had exposed himself by assuming the main roles of the expedition. And this expedition was carried out on the wave of previous success with the *Norge* in 1926, despite the policy of Italo Balbo, the powerful undersecretary of state for aeronautics who was opposed to lighter-than-air aircraft.

The structural failures that are possible causal or contributing factors to the *Italia* crash are listed in Table 3,

with estimates of how likely they were to have occurred. As well as being based on conjectures, the possible causes of these structural failures, and the role they played in the disaster, are unclear (see also the detailed analysis made by Trojani [1964: 727–737]). For example, envelope deterioration could have been caused by the heavy snow clearing operations that were carried out with inappropriate means the days before the last mission (Nobile 1930).

In the analysis of aviation accidents today, the cause of an accident is unlikely to be attributed exclusively to a single factor such as crew member or pilot error. Instead, “aviation accidents are the end result of a number of causes, only the last of which are the unsafe acts of the aircrew” (Shappell & Wiegmann 2000). Using a root cause analysis for the investigation of accident or incident causation, it is possible to identify many types of human failures within the sequence of events up to the highest organizational level. One methodology is the Human Factors Analysis and Classification System, which was developed to identify common root causes among aviation-related accidents and is widely used in various high-risk military and industrial sectors. It is based on Reason’s (1990) theory of error causation by latent and active failures, using the “Swiss cheese” model. According to this model the causes of accidents occur at four levels, each influencing the next. Going backward in time, initially there are active failures or “unsafe acts,” that is, the actual actions of an operator that lead to the event; in other words, it is “what happened.” The next tiers examine in more depth the “why” of error occurrence and describe latent failures progressively as the “preconditions for unsafe acts,” “unsafe supervision” and finally, “organizational influences.” Each layer of organizational defence prevents an undesired consequence such as an accident from occurring by providing a means

of identifying and mitigating an error before it progresses any further. However, Reason (1990) describes “holes” in the various layers, similar in analogy to those in the layers of Swiss cheese. When the holes in the various layers “line up,” providing an unimpeded path through all the layers of defence—so the model goes—then the accident occurs. (For more details and explanation, the reader is referred to Wiegmann & Shappell 2003).

This methodology was used here in the case of the *Italia* only to help investigators better recognize the human failures at various levels. The authors report this analysis as a useful way of reporting and classifying the major human contributing factors to the crash of the airship *Italia*, as revealed by the Commission of Inquiry (Table 4). As such, this list cannot claim to be definitive or exhaustive, but it is of historical interest and may help to understand the overall reasons of the mishap. The main people accused, especially the commander, have already reacted effectively to these accusations in a more or less consistent manner, but unfortunately an analysis of this sort was possible only after the fall of the fascist regime, or later (Nobile 1945; Trojani 1964). In fact, the commission’s remarks are biased, as has been shown, because they consist only of the unfavourable considerations against the commander and do not consider the fact that he and his men were not involved in a routine mission. The endeavour of the *Italia* was a high-risk scientific expedition into the unknown, to which one would have volunteered to participate on the basis of trust. Therefore, not all the safety precautions of routine flights could be applied to this effort.

Apparently, the fact that Nobile held several roles on the *Italia* that were held by Norwegians in the *Norge* expedition (i.e., he acted as the organizer and expedition leader, in addition to serving as aircraft commander and

Table 3 Possible structural, causal and contributing factors to the crash of the airship *Italia* on the morning of 25 May 1928, with evaluation of estimated probability of occurrence. Factors in italics are some indicated by the Commission of Inquiry.

Description of structural/mechanical failures	Estimative probability
<i>Excessive air entering through the “valvolone” (the front air inlet which supplies the ballonnet)</i>	Remote
Massive ice encrustations on the envelope surface	Unlikely
Substantial off-gassing through the automatic relief gas valves forced open (frozen)	Unlikely
Considerable gas leak from the aft bags due to tearing(s) in the upper outer cover, <i>perhaps in connection with the removal of snow from the upper surface of the airship before the last flight performed with inadequate means, dangerous for the integrity of the envelope</i>	Probably
Considerable gas leak from the aft bags damaged by the breaking of the stern reinforcement	Unlikely
Considerable gas leak from the aft bags damaged by the breaking of some stern girder beams	Possibly
Block in stern air compartments discharge ducts due to ice encrustations or bending, with hyperpressure in the aft gas bags and automatic opening of the valves	Unlikely
Rapid and massive cooling of lift gas after returning below the cloud layer	Probably
Consistent lift gas heating above the cloud layer with automatic off-gassing	Probably
Downdraft cold air column due to atmospheric disturbances	Remote

Table 4 Possible human factors, indicated by the Commission of Inquiry (1929), contributing to the accident of the airship *Italia* on the morning of 25 May 1928. Description is from the report of the commission (MM 1930) translated or summarized by the authors. Taxonomic categories are from the Human Factors Analysis and Classification System (Wiegmann & Shappell 2003).

Causal factors	Description	Remarks
Unsafe acts		Assumed active failures by command, pilot or crew
Decision errors: poor choice	The lift-loss was “due to completely natural causes and dependent on the incorrect manoeuvres” performed: lift gas venting during the first accident with loss of “prudent lightness.”	The commander chose to arrest the static lift by releasing some amount of gas, below and above the cloud layer, to control the ascent instead of using the engines; above the clouds the airship was heated by direct sunlight.
Decision errors: poor choice	At the final moments the airship, continuing to descend, came to the left and described a wide semicircle, disposing with the stern to the wind: the commander sought for a field of snow to land on, instead of directing the ship with the bow in the wind.	The landing in favour of wind was against “normal piloting rules,” but the airship, because of her abnormal attitude (tail-down), no longer responded to the rudder.
Decision errors: inappropriate manoeuvre	The rudder was abandoned (by Malmgren) and then, after a while, the General took it; the engines were stopped late “only when it was already very close to the ice”; so the airship, uncontrolled, made a large semicircle disposing itself with the stern in the wind; she took a high speed by adding her own to that of the wind; the crash of the airship occurred therefore at a speed of about 100 km/h and “this largely explains the disaster.”	Commission stated that “if the airship had been manoeuvred according to normal piloting rules, it could still have been possible to avoid such a disaster” or “the effects would in any case have been reduced.” But impediments to piloting were the same as that of the previous point and the time allowed for the manoeuvres was very short.
Skill-based error	(a) Excessive compensation with the elevator in the hard down position due to attention failure or poor technique by the operator at the elevator-wheel during the first accident. (b) Having left the helm unattended for a few moments before the crash.	(a) Trojani was the elevator-wheel steersman at that time. (b) Malmgren was the helmsman who left the helm.
Skill-based error: omitted step in procedure	Excessive air entering through the “valvolone” (the front air inlet which supplied all the ballonnet) because it was inadvertently left open by the elevator-wheel steersman. Having put the engines at full strength ahead, without closing or reducing the opening of the “valvolone,” caused a greater leakage of gas that dangerously worsened the situation.	This hypothesis is wrong. See text for details.
Preconditions for unsafe acts		Assumed latent failures
Adverse mental and physiological states: mental and physical fatigue	Excessive work time requested on board. (a) The second flight lasted 69 hours, without any manoeuvring crew rest. (b) At the final moments the crew was “obviously exhausted,” having been in flight for at least 54 hours.	The Commission reported that the 12 hours maximum operational limit should not be exceeded, in order not to risk it becoming “dangerous for the regular and timely execution of the manoeuvre.”
Crew resource management: poor aircrew coordination	(a) Service assigned to Viglieri and Trojani on board was not exactly defined. (b) There were “undecided orders, imperfect organization on board and also on the ground ... the feeling of a vague command, almost absent, as shown by the interrogations ... it lacked ... in the crew a solid harmony for mutual esteem and for absolute trust in the boss and in the success of the programme undertaken.” (c) Absence of command in a difficult moment: Zappi and Mariano threw as ballast four gasoline tanks despite its shortage during the first accident without commander’s permission.	The statements asserted in (b) were not detailed by commission. The episode of the gasoline tanks launches shows little sense of discipline and appears to cast a negative light on the military personnel who did it.

(Continued)

Table 4 (Continued)

Causal factors	Description	Remarks
Unsafe supervision		Assumed latent failures
Inadequate supervision: failed to provide crew rest	Reduced number of manoeuvring aircrew on board (especially engineer), such as not to allow the change of personnel.	All the engineers, and even the single rigger, were always up to their task despite excessive demands.
Planned inappropriate operations: risk outweighs benefit	Not having postponed the departure of the last flight in order to practice "accurate and minute" checks of the envelope integrity, having had to repair a leak just before the take-off and because "the crew, as usual, were already tired and the weather conditions were not very favourable."	As the hangar had no roof, the snow accumulated in an impressive manner on the top of the airship before the last flight. The snow was cleared by inadequate and ill-equipped operators, who used brooms, mops and shovels, with the risk of causing damage to the envelope.
Planned inappropriate operations: poor crew pairing	No SIC.	See text for details.
Planned inappropriate operations: excessive tasking/workload	"The airship, as shown by the interrogators, had always left Kings Bay with the men already tired, since everyone was held in the hangar for the whole night before the flight: the officers waiting for the moment of departure, the others used for the gruelling and long work of preparing the airship to fly."	
Supervisory violations	(a) Having permitted individuals without any licence to operate as elevator-wheel steersmen. (b) Having allowed only one radiotelegraph operator on board in violation of internal and international air navigation regulations.	(a) Both Cecioni and Trojani, who had aeronautical experience but not the piloting patent, were assigned as elevator steersmen. (b) The second radiotelegraph operator, Pedretti, was left at the base.
Organizational influences		Assumed latent failures.
Resource management: selection, manning	(a) The crew was chosen "among good elements but not with a rigorous selection for both their professional ability and physical resistance." (b) The crew, therefore, "appears as a whole, to not fulfil the criteria of number, physical qualities and technical requirements suggested by the experience and by the same internal and international air navigation regulations." (c) "No one had been subjected to any climate training period and to the inconveniences they were facing." (d) No "experienced dirigibilist pilot" was on board. (e) "Service assignments on board not exactly defined." (f) Viglieri, the third Regia Marina officer, was "not absolutely indispensable on board."	These allegations cannot be the sole responsibility of Nobile, but of all those who were in charge of the organization of the expedition. Nobile (1945) had addressed all these accusations in his book.

pilot, with minimal delegation of responsibilities) made him a very easy target. There are many other operational elements already known in those times that should have been considered in the assignment of faults and accountability, but these were not evaluated at all. For instance, the adverse weather conditions and the extreme cold (today we could add vibration, noise, constant sunlight and circadian dysrhythmia), surely affected the performance of the commander and the crew during the 54-hour flight before the crash. Moreover, the loss of buoyancy of the *Italia* was so rapid that the time available to remedy the problem perhaps exceeded human limits. In fact, the survivors consistently reported that only two or three minutes elapsed between the occurrence of

uncontrolled descent alarm and the moment of impact (Viglieri 1929; Běhounek 1930; Trojani 1964).

Other types of latent failures at the organizational tier, for example, extremely negative political influences, could be included. The factor with the greatest consequences was the partial involvement of the Regia Aeronautica in this expedition, which meant, among others things, that the use of a larger airship already in construction was not authorized (Ferrante 1985).

Applying Reason's (1990) "Swiss cheese" model to the crash of the *Italia*, it is evident that there were "holes" in the various layers of overall organizational and political effectiveness that ultimately led to undesired consequences. It is clear that the allegations of inadequate

piloting in the final phase by the commander were forced and did not take into account important elements that were already evident at the time. What is more, the fault regarding inadequate crew selection and assignment of tasks, charged to Nobile alone, needs to be seen as a latent failure with a wider scope of responsibility that should be shared among the RSGI, the Regia Marina and the Regia Aeronautica itself. A clear fact, not determined by Nobile but rather surely suffered by him, was the impossibility of having at his disposal experienced aeronautical officers of his exclusive trust.

Given these considerations, one can still ask the questions: Should General Nobile have appointed an SIC, and was he at fault for not having done so? One could argue “yes,” as his 1921 papers show that Nobile himself felt an SIC was essential to the flight crew of an airship. Similarly, Amundsen recognized the necessity of having an SIC on the *Norge*, and Nobile was considering Riiser-Larsen, and later Oscar Wisting, for the SIC position on the *Italia*. Nobile later chose not to have Commanders Mariano or Zappi as SIC, ostensibly to prevent rank inversion, and he did not see fit to select either of the two Navy officers available to him. Certainly, there was a reason for an SIC, as the need to relieve a commander from time to time was evident through experience, even if the precise physiology of sleep was not known. Nobile’s decision could be understood at least partially because of his self-perceived personal traits and the undeniable success of the *Norge*. Duration and fatigue were therefore readily apparent to Nobile as being an inevitable part of this expedition. Ultimately, not to have named an SIC left a large hole in one level of organizational safety.

Conclusions

A major goal of the *Italia* expedition was the pursuit of scientific knowledge, and even critics of today would show a lack of respect for those who perished in this expedition if they did not attempt to extract every lesson to be learned from this endeavour, so as to apply it to future exploration attempts. That is indeed the best way to commemorate the memories of the *Italia* crew members, including her commander. In this manner and to this day, the *Italia* continues to educate those willing to take time to truly understand her lessons, distilled though they are through the filter of time. It is in this spirit—one of respect rather than of criticism—that this work has been written.

General Nobile undoubtedly reflected the culture of his time, a culture in which the heroic mindset born in an age of exploration was still very much alive (Maxtone-Graham 1988; Wilkinson 2012; Bart 2013). The

reasoning is that great men are destined to accomplish great things, and perhaps Nobile considered himself to be a great man of history, one destined to leave his mark (Carlyle 1888). These great accomplishments are often achieved at the cost of great discomfort to individuals themselves in terms of enduring cold, hunger, thirst, sleepiness, loneliness, despair, depression, interpersonal conflict and obstacles to mission success. But in the minds of great men such discomforts serve only to clarify and refine those qualities that make them great. Discomfort is the cost of great achievement. For Nobile it was his self-assured belief that he could push through the personal comforts of warmth, food or rest, and still maintain his ability to command an airship on an expedition to and from the North Pole. This would be particularly true for that comfort that some would call the hedonic pleasure of sleep. In his mind the cost of weariness was minor in the face of so great an undertaking, as it was up to him to follow his destiny. Though this line of reasoning may now appear a bit wayward to those for whom the physiology of sleep and its effect on performance is much more clearly understood, the effort and the selflessness demanded of the hero-commander is nonetheless admirable.

The lesson to be learned here is that the leader and commander of the *Italia* expedition, General Nobile, did indeed make a mistake in proceeding on the mission of the *Italia* without an SIC. While there are certainly other causes and contributing factors to be considered, the commander’s fatigue was clearly a cause or contributing factor in the ultimate result. The decision not to have an SIC, regardless of the difficulties encountered in selecting his officers, was his and his alone to make, and he was not sleep-deprived when he made it. He overestimated his ability to carry his duties in the absence of a deputy who could provide relief. He also loaded onto himself the very challenging organizational and strategic tasks of a new mission, unlike the previous one where he could concentrate only on the command and preparation of the airship *Norge*. Nobile certainly recognized the need for relief in other crew members, such as rudder operators and engine mechanics, but he undervalued this need in himself. Though this was undoubtedly caused largely by the overall success of the *Norge* expedition, he unfortunately did not appreciate his lapses in performance during that flight, nor the mission-saving benefit provided by the SIC, Riiser-Larsen. The failure to learn adequately all the lessons provided by the *Norge* expedition was part of the greater error in judgement by Nobile with respect to the *Italia*.

Explorers today must continue to recognize the importance of human performance, and its inevitable variability, for mission outcome. Humans have the capacity for creative thought and innovation, which are qualities

necessary in solving the unforeseen problems inevitably encountered when exploring the unknown. As such, humans would always be a key component in the success of exploration missions. Nevertheless, humans have their limitations. They get tired, feel cold, hungry, thirsty, depressed and lonely. At times they do not communicate well. They lose situational awareness and make mistakes. These traits are not a fault of moral character, and it is unwise to believe they can be overcome by sheer willpower. Rather, variability in human performance is an inescapable part of human nature.

The attendant risk of human error, however, can be mitigated. Personnel selection, proper training, optimal vehicle design and other such elements of human–systems integration could go a long way in this regard. Another key element is that of redundancy—that is, staffing the mission such that one human can back up the other, and nowhere is this redundancy more critical than in the role of commander. No matter the commander's level of self-confidence in his or her own abilities, the good commander must recognize variability in human performance, starting with himself or herself. And he or she must plan accordingly. Likewise, the organization surrounding any such effort must appreciate the detrimental aspects of sleep deprivation and fatigue. Unfortunately, Nobile did not plan accordingly, and his excessive fatigue was a direct result that most likely contributed heavily to the crash of the *Italia*.

History tells us that Nobile and his fellows must be recognized as true explorers who ventured into the unknown. They had the courage to attempt something new in an endeavour that all participants surely realized guaranteed no safe return. In many respects, based on the overall scientific knowledge obtained from the *Italia* expedition, the efforts of Nobile and his crew were successful, and for this they must be given the credit. The only true failure of the *Italia* expedition would be to not glean this important lesson of history, the ultimate reason for its crash, and the deaths of no few members of her crew.

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Disclaimer

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Author SA is the grandson of crew member Renato Alessandrini, who was lost in the crash of the airship *Italia*.

References

- Aas S. 2003. "One man's foolishness led to the death of 14 men." Norwegian reactions to Umberto Nobile and the "*Italia*" disaster. *Acta Borealia* 3, 169–194, doi: 10.1080/08003830310003164.
- Aas S. 2005. New perspectives on the *Italia* tragedy and Umberto Nobile. *Polar Research* 24, 5–15, doi: 10.3402/polar.v24i1.6249.
- Alessandrini S. 2019. *In dirigibile al Polo Nord. Storia di Renato Alessandrini, dalla prima trasvolata dell'Artide col "Norge" all'ultimo volo con l' "Italia."* (By airship to the North Pole. The story of Renato Alessandrini, from the first transarctic flight by the airship Norge to the last flight of the Italia.) *Memorie Vol. 93*. Rome: The Italian Geographical Society.
- Alhola P. & Paivi P.K. 2007. Sleep deprivation: impact on cognitive performance. *Neuropsychiatric Disease and Treatment* 3, 553–567.
- Amundsen R. 1927a. *My life as an explorer*. New York: Doubleday, Page & Company.
- Amundsen R. 1927b. Roald Amundsen's "inside story" of the rows aboard the *Norge*. The explorer complains that Nobile nearly wrecked the airship over the Arctic, but tried to seize the honors. *The World's Work* 54(4), 389–404.
- Amundsen R. & Ellsworth L. 1927. *First crossing of the Polar Sea*. New York: George H. Doran Company.
- Anonymous 1926. Denies Nobile guide ship in polar flight. Ellsworth says credit is not due Italian. Nobile's statement. *Plattsburgh Sentinel*, 20 Jul., p. 1.
- Anonymous 1931. R 101 Simon inquiry report. Disaster due to loss of gas. *Flight*, 3 Apr., pp. 290–291.

- Anonymous 1961. Libel on Italian general: Nobile v. Putnam & Co. Ltd. and Eckener. *The Times* (London), 7 Jul., p. 18.
- Bart S. 2013. *Race to the top of the world: Richard Byrd and the first flight to the North Pole*. Washington, DC: Regnery History.
- Běhounek F. 1930. *Il naufragio della spedizione Nobile. Sette settimane sul pack. (The wreck of the Nobile expedition. Seven weeks on the pack.)* Florence: Bemporad.
- Bendrick G.A., Beckett S.A. & Klerman E.B. 2016. Human fatigue and the crash of the airship *Italia*. *Polar Research* 35, 27–105, doi: 10.3402/polar.v35.27105.
- Biagi G. 1929. *Biagi racconta ... I miracoli della Radio nella tragedia Polare. (Biagi tells ... Radio miracles in the polar tragedy.)* Milan: Mondadori.
- Caldwell J.A. & Caldwell J.L. 2016. *Fatigue in aviation: a guide to staying awake at the stick*. New York: Routledge.
- Caldwell J.A., Mallis M.M., Caldwell J.L., Paul M.A., Jiller J.C & Neri D.F. 2009. Fatigue countermeasures in aviation. *Aviation, Space, and Environmental Medicine* 80, 29–59, doi: 10.3357/ASEM.2435.2009.
- Carlyle T. 1888. *On heroes, hero-worship and the heroic in history*. New York: Fredrick A. Stokes & Brother.
- Crocco G.A. 1945. La mia perizia. (My expertise.) *Rivista Aeronautica* 21, 9–13. Rome: Ministero Difesa.
- Cross W. 2002. *Disaster at the pole: the crash of the airship Italia and the 1928 Nobile expedition to the North Pole*. Guilford, CT: The Lyons Press.
- Doran S.M., Van Dongen H.P. & Dinges D.F. 2001. Sustained attention performance during sleep deprivation: evidence of state instability. *Archives Italiennes de Biologie* 139, 253–267, doi: 10.4449/aib.v139i3.503.
- Durmer J.S. & Dinges D.F. 2005. Neurocognitive consequences of sleep deprivation. *Seminars in Neurology* 25, 117–129, doi: 10.1055/s-0029-1237117.
- Eckener K. 1958. A note on the technology and development of the Zeppelin airship. In H. Eckener (ed.): *My zeppelins*. Pp. 185–216. London: Putnam & Co.
- English D. & Kuzel M. 2014. Reliability of eyewitness reports to a major aviation accident. *International Journal of Aviation, Aeronautics, and Aerospace* 1, 1–21, doi: 10.15394/ijaaa.2014.
- Ferrante O. 1985. *Umberto Nobile. Vols. 1–2*. Roma: Tatangelo.
- Giudici D. 1928. *Col "Krassin" alla tenda rossa. (With the Krassin to the red tent.)* Milan: Moneta.
- Gokhale B.N. 2010. *Report on accident to Air India Express Boeing 737–800 aircraft VT-AXV on 22nd May 2010 at Mangalore, New Delhi*. New Delhi: Ministry of Aviation.
- Goode J.H. 2003. Are pilots at risk of accidents due to fatigue? *Journal of Safety Research* 34, 309–313, doi: 10.1016/S0022-(03)00033-1.
- Harrison Y. & Horne J.A. 1999. One night of sleep loss impairs innovative thinking and flexible decision making. *Organizational Behavior and Human Decision Processes* 78, 128–145, doi: 10.1006/obhd.1999.2827.
- Harrison Y. & Horne J.A. 2000. The impact of sleep deprivation on decision making: a review. *Journal of Experimental Psychology Applied* 6, 236–249, doi: 10.1037/1076-898X.6.3.236.
- Horne J. & Moseley R. 2011. Sudden early-morning awakening impairs immediate tactical planning in a changing "emergency" scenario. *Journal of Sleep Research* 20, 275–278.
- Killgore W.D.S., Balkin T.J. & Wesensten N.J. 2006. Impaired decision making following 49 h of sleep deprivation. *Journal of Sleep Research* 15, 7–13, doi: 10.1111/j.1365-2869.2010.00904.x.
- Libedinsky C., Massar S.A.A., Ling A., Chee W., Huettel S.A. & Chee M.W.L. 2013. Sleep deprivation alters effort discounting but not delay discounting of monetary rewards. *Sleep* 36, 899–904, doi: 10.5665/sleep.2720.
- Maddalena U. 1930. *Lotte e vittorie sul mare e nel cielo. (Struggles and victories over the sea and in the sky.)* Milan: Mondadori.
- Maddox W.T., Glass B., Wolosin S.M., Savarie Z., Bowen C., Matthews M.D. & Schnyer D. 2009. The effects of sleep deprivation on information-integration categorization performance. *Sleep* 3, 1439–1448, doi: 10.1093/sleep/32.11.1439.
- Maxtone-Graham J. 1988. *Safe return doubtful: the heroic age of polar exploration*. New York: Charles Scribner's Sons.
- MM (Ministero della Marina) 1930. *Commissione d'indagine per la spedizione polare dell'aeronave "Italia." Relazione. (Commission of inquiry for the airship Italia polar expedition. Report.)* *Rivista Marittima* 8. Rome: Royal Navy Ministry.
- Monk T.H. 2007. Practical consequences of fatigue-related performance failures. *Sleep* 30, 1402–1403, doi: 10.1093/sleep/30.11.1402.
- National Transportation Safety Board 1994. *Aircraft accident report: uncontrolled collision with terrain, American International Airways flight 808, Douglas DC-8-61, N814CK, U.S. Naval Air Station, Guantanamo Bay, Cuba, August 18, 1993. NTSB/AAR-94/04*. Washington, DC: National Transportation Safety Board.
- Nelson M.L. 1999. *A digital library for the National Advisory Committee for Aeronautics. Technical Report NASA/TM-1999-209127*. Hampton, VA: National Aeronautical and Space Administration Langley Research Center.
- Nilsson J.P., Söderstrom M., Karlsson A.U., Lekander M., Akerstedt T., Lindroth N.E. & Axelsson J. 2005. Less effective executive functioning after one night's sleep deprivation. *Journal of Sleep Research* 14, 1–6, doi: 10.1111/j.1365-2869.2005.00442.x.
- Nobile U. 1921a. The employment of airships for the transport of passengers: indications on the maximum limits of their useful load, distance covered, altitude and speed. *Technical Notes National Advisory Committee for Aeronautics no. 63*, August 1921. Accessed on the internet at <http://naca.central.cranfield.ac.uk/reports/1921/naca-tn-63.pdf> on 2 October 2019.
- Nobile U. 1921b. The future of aerial transportation in public services. *Technical Notes no. 63. Technical Notes National Advisory Committee for Aeronautics no. 63*, August 1921. Accessed on the internet at <http://naca.central.cranfield.ac.uk/reports/1921/naca-tn-63.pdf> on 2 October 2019.
- Nobile U. 1928a. The dirigible and polar exploration. In W.L.G. Joerg (ed.): *Problems of polar research: a series of papers by thirty-one authors*. Pp. 419–425. New York: The American Geographical Society.
- Nobile U. 1928b. More rows aboard the *Norge*: the Italian commander tells his side of the controversy. *The World's Work* 55(3), 261–265.
- Nobile U. 1930. *L'Italia al Polo Nord. (With the Italia to the North Pole.)* Milan: Mondadori.

- Nobile U. 1931. *With the Italia to the North Pole*. New York: Dodd, Mead & Company.
- Nobile U. 1945. *Posso dire la verità: storia inedita della spedizione polare dell' "Italia."* (I can tell the truth: unpublished story of the Italia polar expedition.) Rome: Mondadori.
- Nobile U. 1961. *My polar flights: an account of the voyages of the airships Italia and Norge*. London: Frederick Muller Ltd.
- Nobile U. 1969. *La tenda rossa*. (The red tent.) Milan: Mondadori.
- Reason J. 1990. *Human error*. New York: Cambridge University Press.
- Riiser-Larsen H. 1927. Refutation of various points in Nobile's lectures in America. In R. Amundsen (ed.): *My life as an explorer*. Pp. 270–277. New York: Doubleday, Page & Co.
- Samoylovich R. 1930. *S.O.S. nel mare artico. La spedizione di soccorso del Krassin*. (S.O.S. in the Arctic. The Krassin rescue expedition.) Florence: Bemporad.
- Segrè C.G. 1990. *Italo Balbo: a fascist life*. Berkeley: University of California Press.
- Shappell S.A. & Wiegmann D.A. 2000. *The human factors analysis and classification system—HFACS*. DOT/FAA/AM-00/7. Washington, DC: Office of Aviation Medicine, Federal Aviation Administration.
- Tomaselli F. 1929. *L'inferno bianco. Racconto della spedizione Nobile con 94 illustrazioni fuori testo*. (The white hell. The Nobile expedition tale with 94 out of text illustrations.) Milano: Unitas.
- Trojani F. 1964. *La coda di Minosse*. (The tail of Minos.) Milan: Mursia & Co.
- Venkatraman V., Chuah Y., Huettel S.A. & Chee, M.W.L. 2007. Sleep deprivation elevates expectation of gains and attenuates response to losses following risky decisions. *Sleep* 30, 603–609, doi: 10.1093/sleep/30.5.603.
- Viglieri A. 1929. *48 giorni sul "pack."* (Forty-eight days on the "pack.") Milan: Mondadori.
- Wiegmann D.A. & Shappell S.A. 2003. *A human error approach to aviation accident analysis. The human factors analysis and classification system*. Burlington: Ashgate.
- Wilkinson A. 2012. *The ice balloon: S. A. Andrée and the heroic age of Arctic exploration*. New York: Alfred A. Knopf.
- Wise R.A. & Safer M.A. 2012. A method for analyzing the accuracy of eyewitness testimony in criminal cases. *Court Review: The Journal of the American Judges Association* 48, 22–34.
- Zani L. 2003. Between two totalitarian regimes: Umberto Nobile and the Soviet Union (1931–36). *Totalitarian Movements and Political Religions* 4(2), 63–112, doi: 10.1080/14690760412331326128.