Annals of MIRCE Science

"MIRCE Science is a theory of the motion of functionability through working processes, compelled by imposing natural and human actions, defined by Mirce Functionability Equation."

Dr J. Knezevic, Founder, 1999

Mirce Science: Impact of Bed Bugs Infestations on Functionability Performance of Commercial Aircraft

Dr Jezdimir Knezevic[1]

[1]MIRCE Akademy, Woodbury Park, Exeter, EX5 1JJ, United Kingdom

Abstract

Flights cancellations caused by bed bug infestations of commercial aircraft have significant impact of their functionability performance. Thus, this paper addresses bed bugs infestation as an observed phenomenon from the Mirce Science point of view, which means that it is considered as a mechanism that generates negative functionability events, which compels the affected aircraft out of scheduled service. The paper briefly examines the bed bug species to understand their physiological characteristics and life cycle phases, as a natural functionability action that could generate undesirable negative consequences to the travelling public and financial losses to the airlines due to the withdrawal from service of the affected aircraft. Several methods for eradicating bed bugs from infected commercial aircraft surfaces are briefly presented in the paper, as the potential positive functionability action, performed to return them to scheduled working processes.

Key words: Mirce Science, functionability actions, bed bugs, commercial aviation, eradications methods

Citation: Knezevic, J., Mirce Science: Impact of Bed Bugs on Functionability Trajectory of Commercial Aircraft, Annals of Mirce Science. MSA2025-01-26, Mirce Science, Exeter, UK, 2025.

Published: 26 January 2025

MIRCE Science unique identifier: MSA2025-01-26

1. Introduction

The philosophy of Mirce Science is based on the premise that the purpose of existence of any working process is delivery of functionability[1] through time. It is quantified by the measures of the motion, like miles travelled, units produced, energy supplied and similar. However, experience teaches us that at any instant of operational process there is a probability of work being interrupted by occurrences of negative functionability events, resulting from failures of consisting components, natural causes, human actions or their interactions. As every action generates reaction, for the working process to resume functionability it is necessary for humans to undertake appropriate positive functionability actions, like: completion of required maintenance tasks, change the mode or location of operation and so forth. Thus, a working process could be considered as the time evolution through functionability states, compelled by imposing natural of human actions. [1]

The New York Times [2] reported that in March 2024 a passenger on Turkish Airlines flight from Johannesburg to Istanbul noticed a small bug crawling on her seat when she got up to use the restroom. She photographed the bug on her seat and called over the flight attendant, who disposed of the bug. However, her complaints to Turkish Airlines were met with denials, despite her photographic evidence! The same source stated that on 5th October 2024, passengers who were flying from Istanbul to San Francisco had seen bed bugs falling from the ceiling of the aircraft onto the seats and the passengers. Multiple passengers were asking to move seats after discovering the bugs, and one of them was even relocated to the flight attendant jump seat. Only three weeks later, a science teacher found bed bugs on the 10-hour flight from Washington Dulles to Istanbul. She documented 13 bite marks across her body after the flight.

By no means are appearances of bed bugs related to Turkish Airline alone. For example, during the 2018 flight between New York and Mumbai, one business class passenger even tweeted out pictures of bedbugs onboard, leading to the temporary grounding of two Air India planes[2]. Furthermore, in 2017 customers on a British Airways flight reported seeing bed bugs creep out of their seatback screens like a scene from a horror movie[3].

The first recorded observation of insect infestation in air transport was reported by Kisluik[4], who inspected the German airship Graf Zeppelin that landed in New Jersey in October 1928. He found 10 species of insect pests onboard, including one “bug”.

Commercial aircraft are cleaned and inspected regularly, and airlines take measures to prevent and address bed bug infestations. The process typically takes two to five days and can cost airlines between 75,000 and 125,000, USD, when accounting for lost revenue and treatment expenses. Sometimes, the aircraft pulled out of scheduled service requires a spare aircraft that is suitable for long-distance routes, which causes additional pressure to airlines, particularly when passengers report infestations during the flight.

---

[1] Functionability is the ability of a working process to deliver measurable function(s) with expected performance and required attributes. [1]

[2] https://www.bbc.co.uk/news/world-asia-india-4496423

[3] https://www.independent.co.uk/travel/news-and-advice/british-airways-passengers-bedbug-bites-covered-apology-vancouver-london-flight-heather-szilagyi-a8010536.html#:~:text=British%20Airways%20has%20apologised%20after,seat%20in%20front%20of%20her.

[4] https://www.cabidigitallibrary.org/doi/full/10.5555/19290501301

The main objective of this paper is to expose the commercial aircraft design community to the observed phenomena of the infestation of commercial aircraft by bed bugs, as one of many in-service negative functionability actions that shape their functionability trajectory and work done. Therefore, this paper briefly examines the bed bugs species to understand their characteristics and impacts on the travelling public as mechanisms that could generate undesirable negative consequences to the in-service life of commercial aviation. The method for protecting the travelling public from bed bugs was examined in the paper together with their economic and scheduled impacts of airlines affected.

2. The Brief Overview of Mirce Science

In accordance to Mirce Science philosophy, [1] from a functionability point of view, working processes could be in one of the following two states:

- Positive Functionability State (PFS) – functionability is being delivered
- Negative Functionability State (NFS), functionability is not being delivered, for any reason whatsoever.

The motion of working processes through functionability states is a physical manifestation of the impacts of compelling natural and human actions, which in Mirce Science are classified as following:

- Positive Functionability Action (PFA), a generic name for any natural process or human activity that compels a given functionability process type to move to a PFS
- Negative Functionability Action (NFA), a generic name for any natural process or human activity that compels a functionability process to move to a NFS.

The motion of working process through the functionability states is manifested through the occurrences of functionability events which, according to Mirce Science philosophy, are classified as following:

- Positive Functionability Event (PFE), a generic name for any physically observable occurrence that signifies transition from a NFS to a PFS,
- Negative Functionability Event (NFE), a generic name for any physically observable occurrence that signifies the transition from a PFS to a NFS.

Consequently, the functionability performance through time is directly determined by the duration of times that working processes spent in functionability states. The pattern generated by the motion of functionability process through functionability states, in respect to the passage of time, forms the functionability trajectory, which is uniquely described by Mirce Functionability Equation [1]

The remaining part of the paper focuses on the bed bugs as one of many negative functionability actions generated by the natural or human actions that directly impact the motion of functionability of working processes of a commercial aircraft.

3. Cimex Lectularius (Common bed bug)

Bed bugs are small wingless insects that feed solely upon the blood of warm-blooded animals. They are sometimes mistaken for ticks or cockroaches. Bed bugs are sometimes called "red coats," "chinches," or "mahogany flats."

Human bed bugs were virtually eradicated from the developed world in the middle of the 20th century. However, as of the first decade of the 21st century, bed bugs are back and spreading. Bed bug infestations have been reported from all over the US and Europe. Together with bat bugs, swallow bugs, and poultry bugs, they belong to the family Cimicidae in the suborder Heteroptera or true bugs (order Hemiptera). They comprise less than 100 described species worldwide, but their notorious habits as temporary ectoparasites of birds and mammals, including humans, and the unusual mode of reproduction known as traumatic insemination[5] have made this small group of true bugs infamous.

3.1 Morphology and relationships to other bugs

Bed bugs are small to medium-sized, 4-10 mm, ovate, squashed-looking from top to bottom and of brownish coloration. Their wings are represented by short, non-functional wing pads and they cannot fly. They have sucking mouth parts, and metathoracic and abdominal scent glands that produce a characteristic smell. The mouthparts comprise the labium[6] and pairs of maxillary and mandibular stylets that form the salivary and food canals. Bed bugs have several specialised features in common with some closely related groups, such as loss of simple eyes known as ocelli[7].

Bed bugs are closely related to the blood-feeding, bat bugs and predatory minute pirate bugs (family Anthocoridae). The Cimicidae are divided into 22 genera, with 12 being exclusively associated with bats, 9 with birds, and only the genus Cimex containing a mixture of bird and mammal ectoparasites. Only three species may be associated with humans, Cimex lectularius in temperate and subtropical regions worldwide, Leptocimex boueti in certain areas of West Africa and Cimex hemipterus in the tropics.

3.2 Natural history

Bed bugs belong to one of only three lineages within Heteroptera that are obligate blood feeders. Similar to other obligate blood-feeding insects, cimicids have microbial symbionts in specialised organs that are presumably important for supplementing the blood diet. The human bed bug subsequently spread with its new host around the world as people migrated with their belongings.

Due to the inability to fly, bed bugs are reduced to passive transportation by their host to spread. Thus, they may “hitchhike” in suitcases, used furniture, and clothing. Even more, an adult bed bug can survive for more than a year without a blood meal. Upon arriving at a new location, the prodigious fecundity of an undetected bug, 200-500 eggs per adult

---

[5] Traumatic insemination, also known as hypodermic insemination, is the mating practice in some species of invertebrates in which the male pierces the female's abdomen with his aedeagus and injects his sperm through the wound into her abdominal cavity (hemocoel).
[6] externally visible part of the “beak”
[7] https://cisr.ucr.edu/invasive-species/bed-bugs

female, ensures a rapid increase in their numbers.

Bed bugs are nocturnally active with peak feeding activity occurring after midnight. They feed on blood about once every 1-2 weeks, while the host is inactive or sleeping.
Feeding requires about 5-10 minutes to complete and generally occurs on areas of the body that are exposed while sleeping, such as the face, neck, arms, and hands. Bites may itch and a rash may develop around the bite. Bed bugs locate a host by orienting toward cues including heat, CO_2, and host odours.

While not feeding, bed bugs are generally concealed in cracks and crevices in their environment, including bed frames, head boards and mattresses. Their affinity to move away from light (negative phototaxis) and they ability to respond positively to tight spaces (positive thigmotaxis) makes them very difficult to locate during daytime hours when they are hiding.

At resting places, bed bugs usually form aggregations of adults and immature stages that are maintained by aggregation pheromones and mechanical cues. When bugs are disturbed, substances emitted from scent glands function as alarm pheromones that drive dispersal and aggregations break up as bed bugs flee danger.

Apart from obligate blood feeding and host interactions, their unusual reproductive behaviour has stimulated considerable research on bed bugs. Reproductive biology of Cimicidae is characterised by traumatic insemination, where sperm is not injected into the genital tract, but rather introduced into the female bed bug after the male pierces the female’s body wall with his reproductive organ. Traumatic insemination systems show tremendous species specific differences ranging from absent or simple to very complex and the study of reproductive structures used in this type of mating may provide insights into the evolution of this unusual mating strategy in the Cimicidae. Immature bed bugs (nymphs) release a chemical signal or pheromone to communicate their non-reproductive status to males, thereby protecting them from male mating attempts which might otherwise be very damaging.

While some viruses have been shown to persist within bed bugs for several weeks, their role in the transmission of human pathogens appears to be negligible. However, bed bugs are serious nuisance pests. Infestation rates of human dwellings with bed bugs may reach 100% in some temperate regions and as many 5,000 bugs may infest a single bed!

They are mainly nocturnal and reach peak activity before dawn. They rest and lay their eggs in crevices and behind wallpaper. When seen on a wall, they resemble mobile brown lentils. Although flightless, bed-bugs can run extremely fast, particularly in warm weather.

4. Bed Bugs, Humans and Infestation Management

The long and disturbing shared history of humans and bed bugs is reflected in language and legend. All Indo-European, African, and Oriental languages have names for bed bugs and these unpopular companions are mentioned in ancient Greek literature as well as the Talmud and the New Testament. Human sensitivity to the bite of a bed bug ranges from insensitive to severe immune reactions, and depends in part on the level of past exposure. Many people will develop hypersensitivity to bed bug bites following repeated feeding by bed bugs. [3, 4]

An infestation of bed bugs is usually identified by finding the bugs or their dark coloured fecal stains in the seams of mattresses and box springs, behind headboards and peeling wallpaper, or in other cracks and crevasses near a sleeping area. The use of a strong flashlight will help in their detection because their strong aversion to light results in considerable movement. Heavy infestations are sometimes associated with a “sweet” odour. Trained dogs provide a very efficient means to detect bed bug infestations, especially when abundance is low, because the dogs can quickly determine by smell whether bed bugs are present in a room. Bed bug traps using CO_2 and heat to attract the bugs may also be useful to identify infestations when bed bug abundance is low.

Management of bed bugs within an infested premise is typically achieved using insecticides, though methods such as targeted vacuuming and heat treatment may also be utilised. The recently discovered pheromone which protects immature bed bugs from mating attempts by males has generated some interest as a possible control mechanism. Application of this pheromone to bed bug aggregation sites within an infested home may reduce male mating even with mature females and this could cause populations to collapse.

5. Bed Bugs Eradication Systems

Substantial analysis of the bed bugs eradication methods and experimental trails related to their effectiveness are presented in [5]. A very brief summary of this extensive research is presented here. Thus:

- Methyl bromide fumigation was the benchmark that all treatment systems were measured against. The closed nature of aircraft favour a fumigation based approach and the non-corrosive, non-flammable properties made this system well accepted. According to Juson (2014) this is only treatment strategy that achieved 100% eradication in a single treatment. However, as methyl bromide depletes the ozone layer, many countries in the world have phased out its production and consumption.

- Chemical treatment replaced the band methyl bromide approach to aircraft fumigation. However, the complex nature of aircraft seating products and the restrictions on dismantling seats does not allow the technician access to properly apply a pesticide. Chemicals require multiple applications over an extended period of time and present health concerns and allergy risks to passengers and crew. [8] None of these other treatments will effectively sanitise the aircraft for viruses, allergens, and bacteria.

- Freezing can be also used to treat bed bugs, with a significant drawbacks or risks. It is contact-based system, which means, if the equipment does not touch the bugs they will survive. Hence, according to Romero et al., (2007) it is unlikely that this method will achieve the levels of control needed for the travelling passengers of commercial aircraft.

- Heat treatment has many supporters in the aviation industry, as it is an environmental manipulation technique. [7] The levels of control achieved are the closest to methyl bromide fumigation. If carried out correctly it has no deleterious effects on the aircraft. However, close attention needs to be paid to temperature monitoring to ensure safe treatment and the desired level of control. In one recirculating system treatment overheating of the environment resulted in warping of plastic components in seating products and cabin side walls. The need to use either fluid transfer or electric filament heaters within the aircraft raised further objections to recirculating heat treatments due to the risk of fire or flood. As only ducted hot air enter the aircraft and the more controllable nature of a forced air systems this has become the favoured eradication system. The increased air turbulence in a forced air treatment capsule results in greater energy transfer to the treatment substrate and consequently a greater reduction in population.

- Scent detection dogs could be used for the accurate and time efficient method for bed bugs detection and control. [6]. However, the complex nature of aircraft seating and regulatory constraints limit drastically reduced the practicality of this method.

6. Thermal Eradication of Bed Bugs in Commercial Aircraft

Thermal eradication is a single-treatment disinsection method for commercial aircraft that eradicates bed bug infestation and sanitises the aircraft at the same time. It has been developed and implemented by Dr Michael R. Linford[8], who designed the equipment for a complete bed bug heat treatment, without sacrificing safety, quality and capability.

Thermal aircraft insect eradication utilises no toxic chemicals, and is both discreet and FAA compliant. Heated air molecules transfer their energy into every surface of the aircraft and cargo hold, allowing all the furnishings and contents of the aircraft to reach a minimum of 60°C. As the equipment used maintains this temperature, bed bugs are successfully exterminated, at all stages of their life cycle. This, extremely effective positive functionability action, regarding eradication of bed bugs in commercial aviation, is completed in hours, when all resources are available.

Treating aircraft for bed bugs by heat, according to the GreenTech Heat solutions technology[9], has the following benefits:

- There is no need to remove soft goods such as cushions, carpet, and bedding for separate treatment
- At the end of the treatment there is no residues of dangerous chemicals
- Extended treatment times at lower temperatures will not damage electronics or avionics
- Return to service immediately following cool down after treatment
- Hypoallergenic
- Bed bugs will be killed at all life cycle states (from eggs through adults)
- Destroys all microbes, viruses, bacteria, allergens, moulds
- Everything can be treated: cabin linings, cockpit, galley, and cargo areas
- Exceeds FAA guidelines for thermal aircraft disinsection
- It will kill any other insects or spiders in your aircraft

[8] GreenTech Heat, https://greentechheat.com/about-greentech-heat.php
[9] https://greentechheat.com/aircraft.php#:~:text=Thermal%20aircraft%20insect%20eradication%20utilizes,%2C%20its%20furnishings%2C%20and%20contents

- It will reduce or eliminate odours from food, smoking, animals, urine, and bacteria in the aircraft treated.

7. Financial Considerations of Eradication of Bed Bugs in Commercial Aircraft

The cost of bed bug management on aircraft is quite variable depending on how the aircraft is employed. Private aircraft, commercial aircraft and military aircraft have very few financial restrictions with regards to the cost of bed bug control. This is because the cost of bed bug management in these aircraft is minimal when compared to the expense associated with even a short flight delay, or even worse flight cancelations. However, domestic medical aviation is often charitably funded and, as a result, very cost conscious. Air ambulance infestations are not common, but they are among the most time-consuming and costly to resolve. This is due to the complex interior structure of the aircraft, which is designed to house medical equipment.

The complex architecture of the aircraft interior limits both visual inspection and treatment ability. In many cases it is not possible to access deep intrusion on the airframe without dismantling the aircraft interior. The widespread use of light honeycomb structures in both aircraft seating and cabin construction allows bed bugs to hide in protected microclimates that are in close proximity to the hosts. These inaccessible surfaces enable infestations to go unnoticed for lone periods of time[10] and make treatment efforts very difficult and costly.

Further obstacles for aircraft disinfestations are the commercial aviation regulations that stipulate that any work carried out on board the aircraft, including pest control, must be overseen by a licensed aircraft engineer. Hence, engineers must be present during the strip-down and re-cover of passenger seating before and after chemical treatment. Engineers also must be present for the removal and reinstatement of heat-sensitive items, such as life vests and emergency exit slides, during thermal disinsection (heat treatment). Needleless to say that these legal requirements increase the cost of bed bug eradiation processes, on one hand, and put further pressure on the pest management crew to complete their treatment as quickly as possible.

In summary, in majority of cases, only the monetary component of a treatment's cost is considered. However, inconvenience, lost reputation, collateral toxicity, time out of service, and length of treatment should all be considered when calculating a total cost.

[10] It is worth pointed out that bed bugs can survive more than 500 days between feedings!

8. Conclusions

The main objective of this paper is to expose the commercial aircraft design community to the observed phenomena of the infestation of commercial aircraft by bed bugs, as one of many in-service negative functionability actions that shape their functionability trajectory and work done.

Bed bugs on commercial aircraft are a part of daily reality of their working processes and as such they are impacting the functionability performance. Most of the airlines have a reactive approach to bed bug management, relying on passenger complaints to initiate the treatment. As the bed bug issue is a global phenomenon the move from reactive bed bug control to proactive management is inevitable

The severity and spread of bed bug activity is obviously directly correlated with duration since the inoculating event. Once established within the aircraft cabin, infestations develop very quickly due to the stability of the environment, extensive harbourage close to the host and the abundance of feeding opportunities. Those airlines that were engaged in a process of proactive detection averaged 80% fewer seats infested and 69% fewer insects in the heaviest seat, when compared with infestations detected by passengers. As preventing the inoculation is not possible, the early detection of infestations is vital particularly in view of reduced efficacy of eradication systems. In view of an aircrafts' likely exposure to bed bugs further research is needed to study passenger boarding behaviour with a view of reducing the rate of inoculation. Seating product design could also be vastly improved to reduce rates of establishment following inoculation and subsequent spread throughout the cabin environment.

9. References

[1] Knezevic, J., The Origin of MIRCE Science, pp. 232, MIRCE Science, Exeter, UK, 2017, ISBN 978-1-904848-06-6

[2] Craggs, R., Passengers Say Turkish Airlines Flights Have Unwelcome Guests: Bedbugs, Travel Dispatch newsletter , The New York Times, 1 January 2025 https://www.nytimes.com/2025/01/01/travel/bedbugs-turkish-airlines-flights.html (accessed 24.01.2025)

[3] Radka, R., 7 Ways to Avoid Bed Bugs on a Plane, Airwatchdog, 2000.https://www.airfarewatchdog.com/blog/50103199/7-ways-to-avoid-bed-bugs-on-a-plane/ (accessed 24.01.2025)

[4] The History of Bed Bug Management – With Lessons from the Past https://agresearch.montana.edu/wtarc/producerinfo/entomology-insect-ecology/BedBugs/BedbugsMangement.pdf (accessed 24.01.2025)

[5] Juson, A.L.R., MANAGEMENT OF BED BUGS ON COMMERCIAL AIRCRAFT, Proceedings of the Eighth International Conference on Urban Pests Gabi Müller, Reiner Pospischil and William H Robinson (editors), Printed by OOK-Press Kft., H-8200 Veszprém, Papái ut 37/a, Hungary, 2014.

[6] Pfiester M., Koehler P., Pereira R., Ability of bed bug detecting canines to locate live bed bugs and viable bed bug eggs. Journal of economic Entomology 101(4): 1389-1396, 2008.

[7] Romero, A., Potter, M., Potter, D., Haynes, K., Insecticide resistance in the bed bug: A factor in the pests sudden resurgence? Journal of medical entomology 44(2): 175-17, 2007.

[8] Romero, A., Potter, D., Haynes, K., Behavioural responses of the bed bug to insecticide residues. Journal of medical entomology 46(1): 51-57, 2009.

[9] Schrader G., Schmolz E., Thermal tolerance of the bed bug. In: n: W.H Robinson and Ana E.C. Campos, eds., Proc. Internat. Conf. Urban Pests, Ouro Preto, Brazil, 315-317, 2011.