Near Ground Lighter than Air Technology Principle and Applications

Defensive Publication

MATTHIAS TAFELMEIER

01 March 2018 (Erding, Bavaria)

CONTENTS

LIST OF FIGURES

ABSTRACT

In this publication, a symbiosis of traditional lighter than air principles with nowadays commonplace drone UAV principles and accordingly contingend fields of engineering and robotics are at the focus of contemplations.

Many status quo physical automation solutions are confined in their effective reach by mediocre stumbling blocks: be it since of technically intractable terrain or obstructive building internal environments, limitations in complexity gait motorics or the state of the art implementations of traction systems. The paper illustrates that a near ground lighter than air airborne solution can be an comprehensive enough alterternative by circumventing ostensibly eludable complexity. That's especially the case for humanoid close range haulage or every days humanoid chores alleviating automation task sets.

In order to outline the doability of the concept, the technical principles are explained on several abstraction and detail levels. A simplest case conceivable device is scrutinized. Further on, various scenarious for different application domains are expounded upon.

The work is to be understood as a introduction to this novel application of lighter than air principles and shall foremost render the knowledge around this field as prior arts.

INTRODUCTION

UAVs and humanoid assisting robotic technologies have entered a plethora of areas of our every day life. Many solutions are already of utmost relevance. Yet, still a vast set of unnecessary chores is obstructing humanity - therebey infringing our physical health, availabe time and further vital resources.

Extending UAVs to more essential use cases of every day life is often down to the shortage of available lift payload to either perform a sufficient haulage effect for transport related tasks or to excert physical forces in more versatile facetes upon the surroundings. With firmer load taking capabilities, such an UAV airborne device can be equipped with a wider set of tooling previously unthinkable and thereby enter a variously fathomable set of domains. Specifically conceived scenarious can be found in the section presenting Application scenarios 3.

Although, from ample media dissemination one could be deceipted towards expecting ground based robotics for the described domains of application are timewise already in nearby reach. Despite the omnipresent claims, in sober engineering circles it's widely accepted that the sophistication level of essential components of comparative ground based devices is technically in its utmost infancies[O'brien(2018b)][O'brien(2018a)]. An exemplative would be motorics elements. Lighter than air facilitated UAVs can pose an immediate interim solution to cover automatable areas, if it's not even in the position to seize the as originally ground based conjured solution manifestation completely.

Certainly, the ligther than air technology put forward is meant for short range haulages and domains. There's a wide range of viable automation options for long haulage usage scenarious already in place in several engineering applicative domains - ground based and airborne. Nevertheless, even for long haulage chores, the concept put forward can be employed to complement certain coverage difficulties frequently encountered for the last mile [Langston(2017)]. With doing the latter, a more economic long haul delivery system can become viable. Efficiency improvements would stem from giving longer stretches of the last mile to the foreseen, more powerful Lighter Than Air - technology principle (LTA) UAVs, especially for payloads of greater magnitude. The device concept presented here is posed to be operated in low range constrained, near ground altitudes formeost in order to profit from the technical advantages of this altitude spectrum without falling short in its attributed complementing role.

The type of UAVs to be introduced shares limitations with most computer embedded systems: limited space, limited power resources, increasing computation requirements. Computational flight control complexity and contstrained lift are adding up to the latter for the airborne nature of the devices being presented.

TECHNICAL PRINCIPLES

Lift Dynamics

In contrast to traditional lighter than air principles applications as for instance found in airship technology [Khoury(2012)], ballonets are not meant to be used as hull stabilizing elements (as in semi-rigids or hybrid airships).

Since of the small scale, lowest alitude of operations and by an ideally strict adherence to rigid lighter than air vehicle principles, there is no need for any internal dynamic stabilization elements. The physcial exhaust heat to expect stemming from adiabatic side-effects of the ballonets frequent proactively conducted compression is technically negligible since of the comparatively puny volumes being orchestrated.

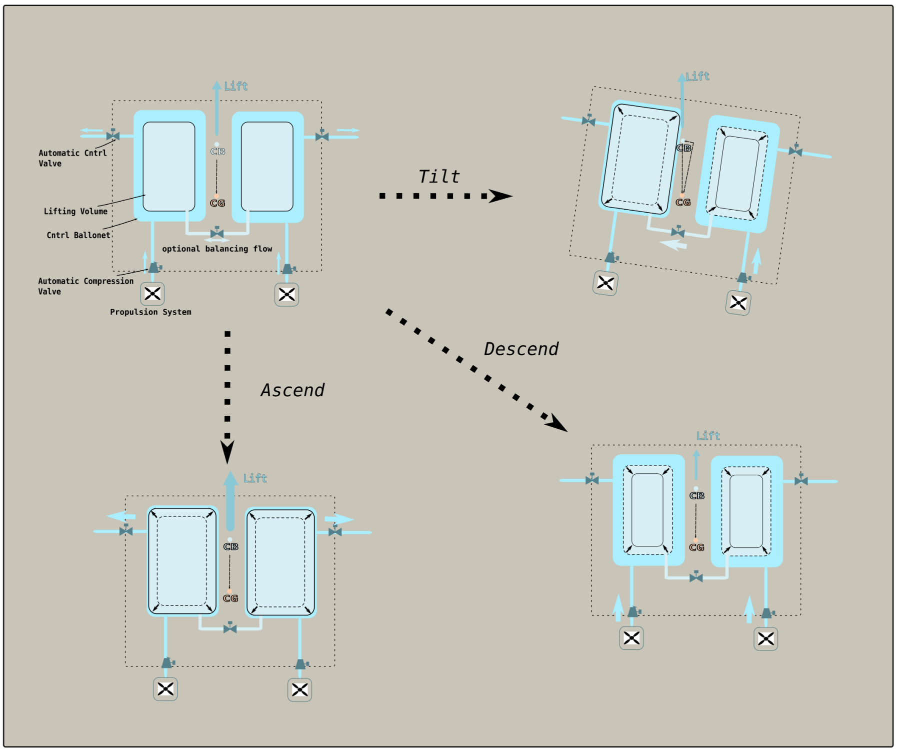

Figure 1: Technical Principle of Lift based motion

Above figure illustrates the abstract components needed to make the lift based operational principle work: the propulsion system for excerting thrust 2.3 and as an optimal intake for the ballonets which are filled with an omnipresent, conventional air mixture. The automatically controlled compression valves are necessary since otherwise no suppressing pressure in the control ballonets could be built up. Automatic control valves are in place to either balance the lift volume gas or to deliberately depressurize the control ballonets.

A tilting movement is effectuated by either pressurizing a subset of lifting volumnes via the ballonets or by unbalancing the lifting gas volumes fillage. Excerting both measures will spur the effectuation, ostensibly. Physically, the actions will shift the centre of buoyancy to a new position over the centre of gravity of the device, thereby tilting the overall vehicle.

A stable, straightly concerted ascend can be realized by depressurizing the control ballonets by airing via control valves. This will grant the lifting volumes room to expand into and thereby increase the perceivably excerted lift. Vice versa, a laterally uniform descend can be brought about by evenly pressurizing the control ballonets via pressurized air being built by the propulsion system coupled up compression valves.

Viable Lift

To illustrate the overall viability of the concept, calculations as to what theoretical lift is attainable with devices following the lighter than air regimental principle stated further up have been conducted and plotted here.

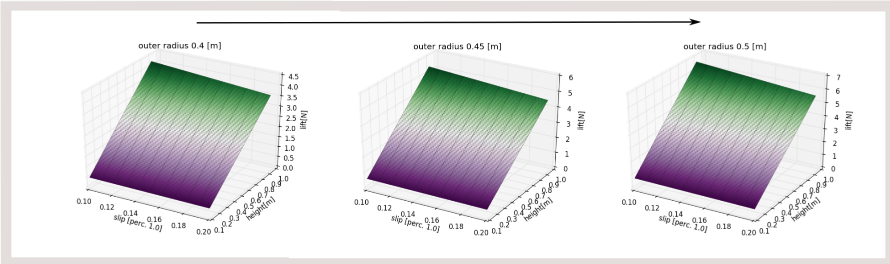

Figure 2: Lift Viability for several outer radius[m] of a cylindrically shaped device

At the core of these plots stands an ostensibly pedestrian calculation.

$$\textbf{Lift} = \pi * \mathrm{height} * \mathrm{outer\_radius}^2 * \textbf{(1-slip\_ratio)} * \textbf{Lift\_Factor} \tag{1}$$

Whereby as **Lift_Factor** the net lift of a cubic metre of helium - a commonplace lifting medium in LTA vehicles - was considered (10.4 N/m^3).

The **slip_ratio** accounts for a varios range of thinkable volume slippages down to design culprits of a specific device. Design specifics could be certain lift volume shapes required for a use case fitted gondola shape.

One can infer from the plots that even in a drastically detrimental device design with a high **slip_ratio**, one can still expect a practically relevant lift that is further superior compared to commonplace UAVs.

Vectored Dynamics

The capabilities of the vectored thrust is certainly down to the sizing, numerousness of propulsion instances, type and degrees of freedom and potentially more factors - therefore no generic statement shall be put here.

The clearer is the set of roles the vectored thrust is taking on: it acts supportative to the lifting dynamical facilities. Decisive will stay the effect of the lifting dynamics equipment, nevertheless, for steadying operations, thrust can assist in ascending or descending lift formation, for keeping an altitdue or a certain position over ground, also know as the hovering scenarious [Khoury(2012)]. The main role will certainly be the authoritative influence taking part in the form of stabilizing the flight operations as to reacting to any physical path taking interspersings or at the point in time of the onset of taking load via the gondola, as the direction enforcing steering mechanism or as a precision granting position readjustment aid.

Embedded Control Automation

As lift dynamics control and vectored device steering can be dauntingly impossilbe for a human to conduct manually, especially for tasks requiring parallelization. These low level steering activities do imply a need for a computing based automated flight control system onboard.

From the principle outline, the actually employed computing devices shouldn't differ significantly from commonplace embedded systems, as both share a similar problem space: limited space, limited power resources, commensurately demanding computational requirements.

Device Proposal

As a first plain, yet common sensical proposal for substantiating the overall technical principle 2.1, a near ground LTA device exhibiting a cylindrical shape is outlined. The cylindrical form was chosen for it being most generic for any near ground use cases, it is being employable in-house and externally to buildings and despite spacial restrictions it's allowing device instances to reach a maximum of utilizable lifting volume.

Central aspects as the specified generatable lift, the manouverability, steerability or stability traits can be altered quite radically by streamlining the shape to certain domains, but the latter has to be done by pontentially sacrificing the genericity advantages of the base proposal brought forward initially.

The following illustrations show the essential compartments of such a device, from various angles and with a differing degree of details.

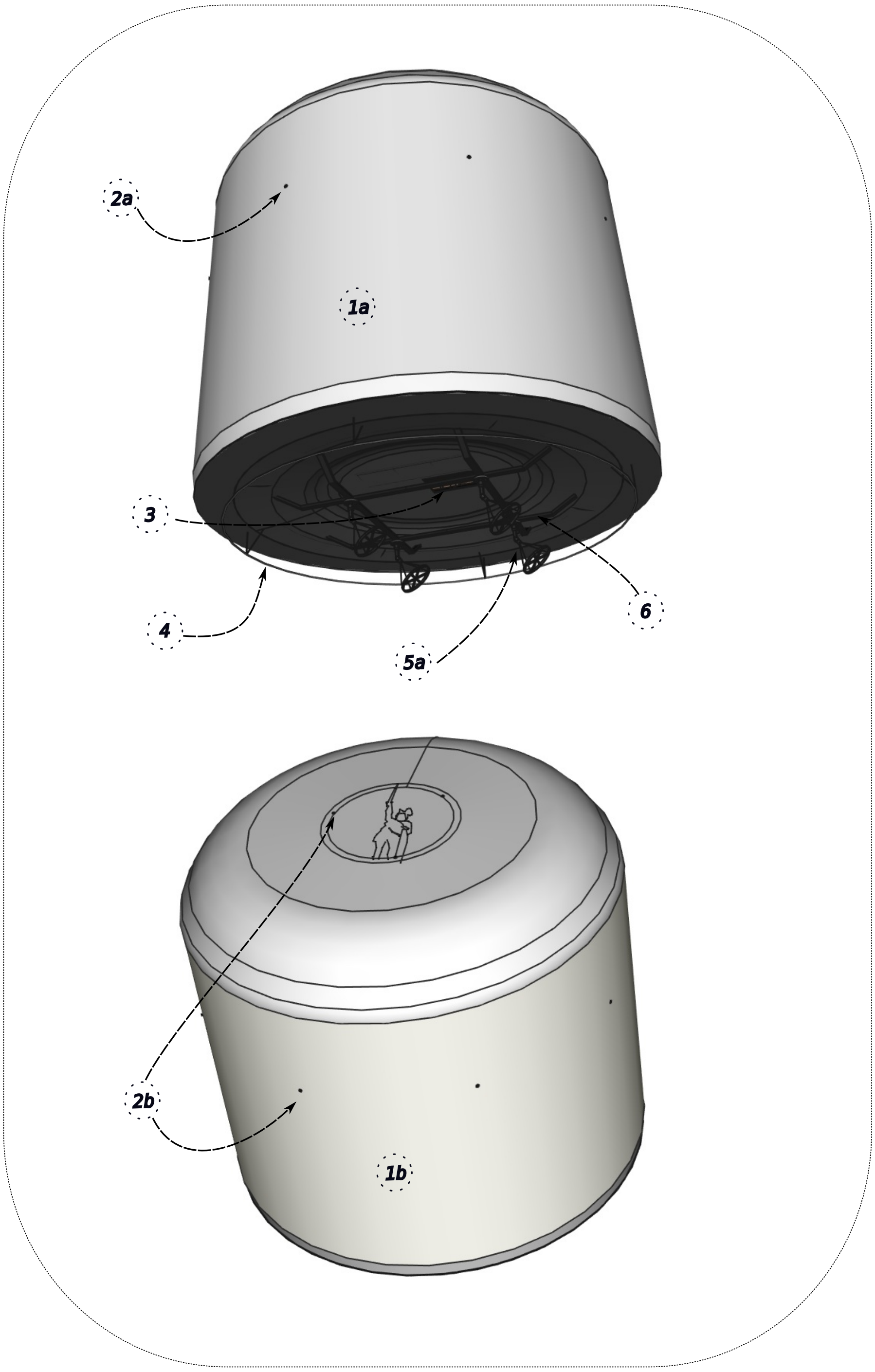

Figure 3: Cylindrical device compartments:

- **1a-b** Envelope
- **2a-b** Flank Ballonet Pressure Exhaust Valve
- **3** Maintenace orifice to Eletrics and Pneumatics core
- **4** Load taking ring
- **5** Vectorized Propulsion System
- **6** Propulsion Bearing

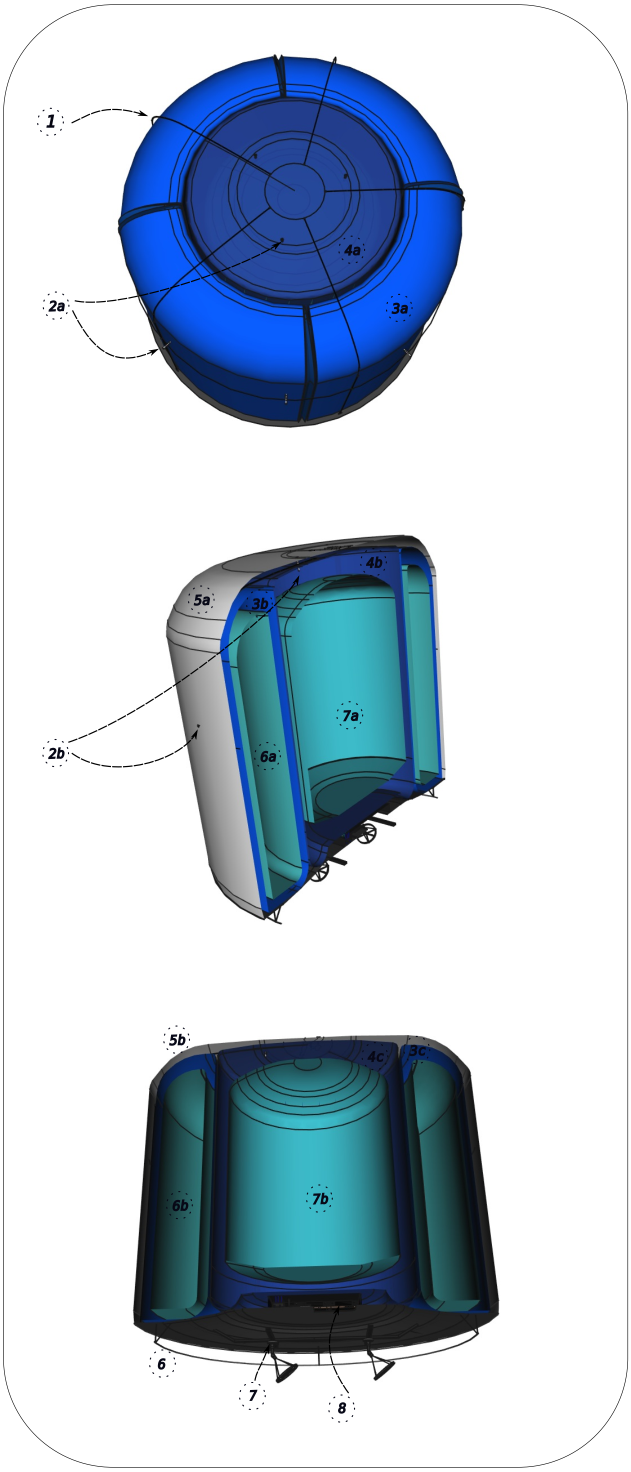

Figure 4: Device cutaway compartments:

- **1** Vehicle Structural Frame
- **2a-b** Ballonet Pressure Exhaust Valve
- **3a-c** Flank Ballonet Section
- **4a-c** Centre Ballonet
- **5a-b** Envelope
- **6** Load taking ring
- **7** Vectorized Propulsion System
- **8** Eletrics and Pneumatics core

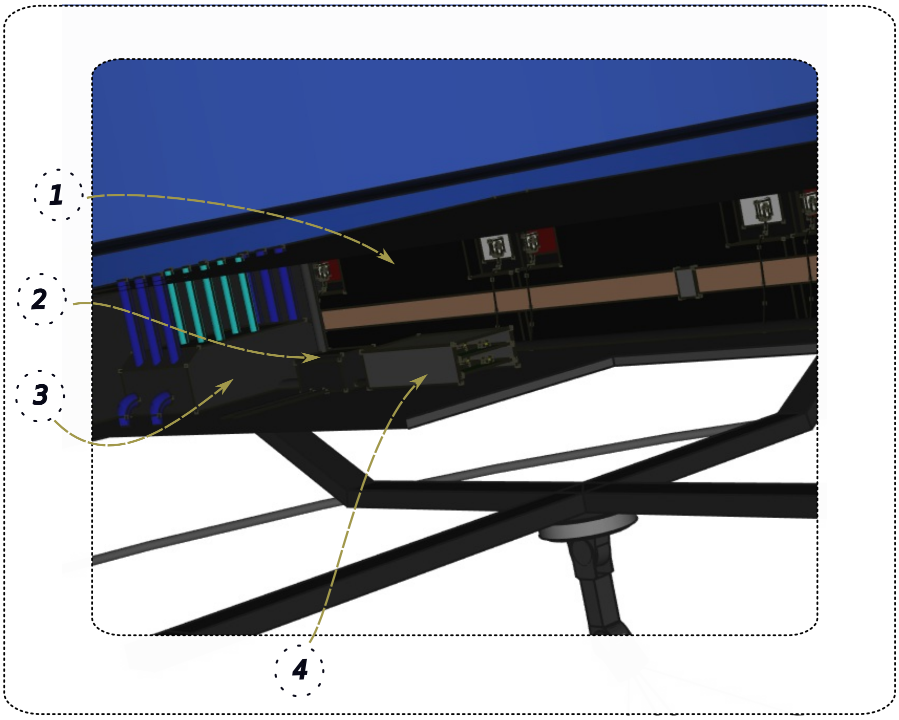

Figure 5: Electrics and Pneumatics Core Compartments

- 1 Battery Unit
- 2 Centralized Electrics Distribution Hub
- 3 Centralized Pneumatics Aggregate
- 4 Onboard Embedded Computing Rack

APPLICATION DOMAINS AND SCENARIOUS

This section is devoted to illustrating application domains for the proposed near ground LTA technology.

Private Sector

Private households are brimming with chores that are ideal candidates for being automated, nigh at least technically assisted or augmented.

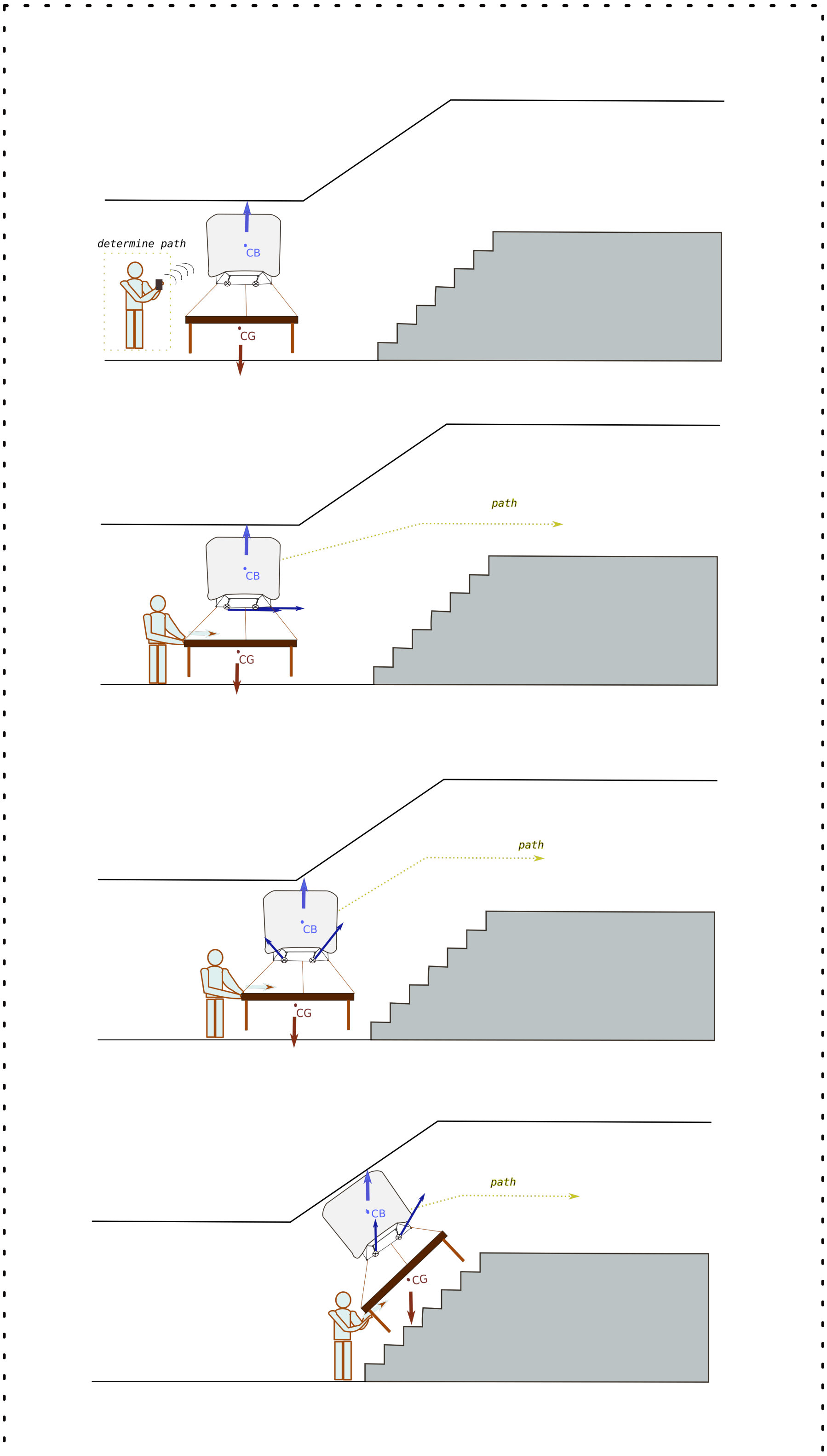

Figure 6: Principle of Private In-Building Haulage

The figure above shows a commonplace problem: one has to transport unwieldy objects but either non-appropriate or none assisting individuals are available for the planned schedule. Having an LTA UAV would allow one to preconfigure the device for the activity and depending on the object assist it at its task or let it conduct the steps automatically. Even when assiting, the flight control of the device shall cover the vaster share of the complex manouvering necessary to not end up in a stalled spacial configuration. Of course, sizing does matter and decides upon the degree of physical human assistance needed. What is more, human health deteriorating effects can be significantly alleviated or even barred out completely by employing an LTA device privately.

The universe of coverable tasks in the private field is vast, especially when configuring the device with according robotic equipment instead of actual payload to be transported. In-house household chores could be conducted in an more varied manner than already covered by ground-based automation solutions like vacuum-cleaners. Through the air-borne nature, all space in-house - even cumbrously reachable parts - could be interacted with in an arbitrarily thinkable form.

Crafting

Crafting is one of the sectors that does profit most from any form of attenuation of physical chores. Risks from physical impairments through work activities is in this sector are comparatively high. Individuals risk limbs, spines skin and further exposed organs regularly. Introducing remote hands corporealising as LTA UAvs does offer an optimal mitigation approach therefore.

Although the human workforce required would be reduced through semi-automation of reoccurrent activities by the devices, there is not even distanly a replacment of individuals in this sector in sight. As the field is stretched from work force perspective, an increasing degree of automation is expected to be embraced rather than shunned. In the future, further convencience improvements could stem from crafting tasks being performed remotely over longer distances, especially for highly repetitive, plain task sets. In additon to an appropriately equipped lowest altitude LTA UAV, stable backbone data networks are necessary for such an appication context.

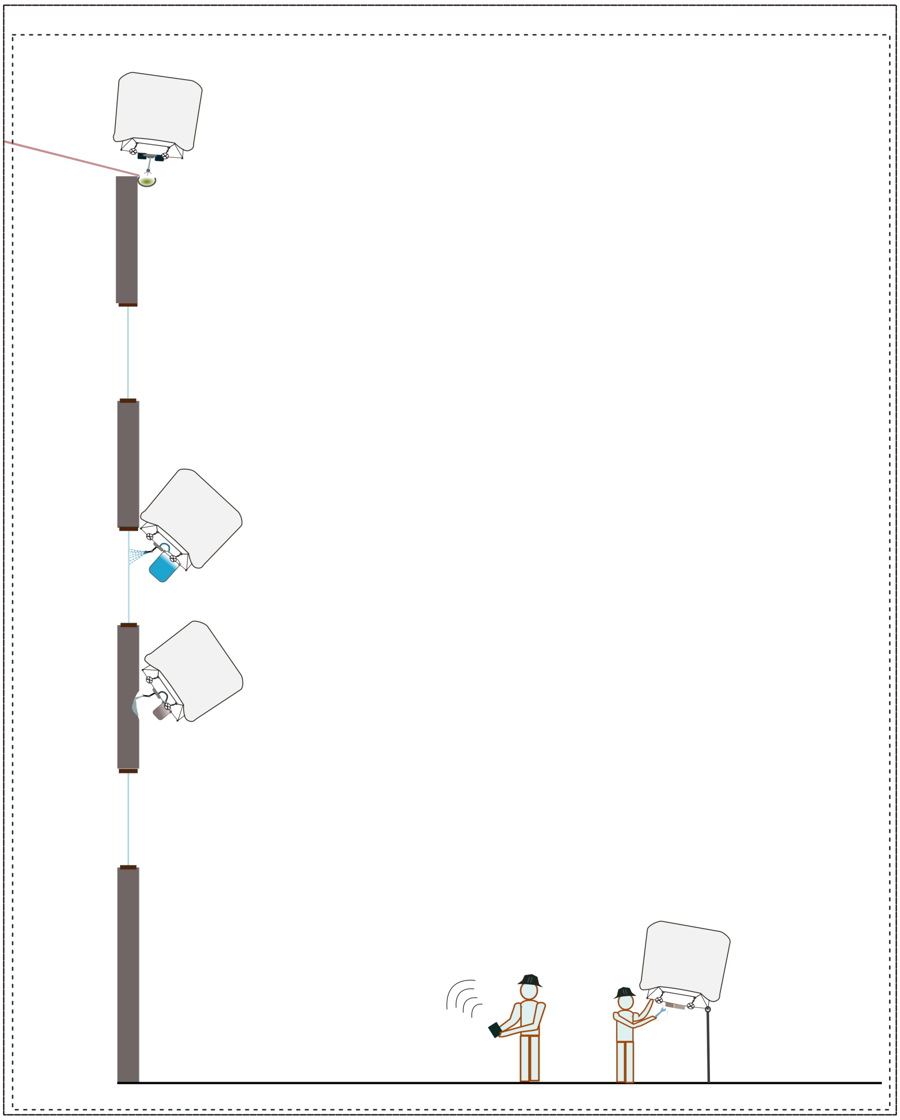

Figure 7: Principle Crafting usage: maintenance of a building facade

The scenario illustration 7 emphasises the versatility of LTA technology through the manifoldly tunable equipment for always meeting the current craftmens operations needs. Moreover, it perfectly depicts another form of physical risk mitigation as it prevents individuals being exposed to heights in this instance.

Although, the given scenario was set building external, nothing is barring crafting industries from benefiting from LTA indoors as specified in the Private Sector passage 3.1.

Health Care

LTA technology, especially the haulage aspects, are certainly not confined to be used for the carriage of non-animate objects. According devices are quite suited for offering impaired patients an additional form of mobility.

Following scenarios present each first an active and then a passive mode of mobility.

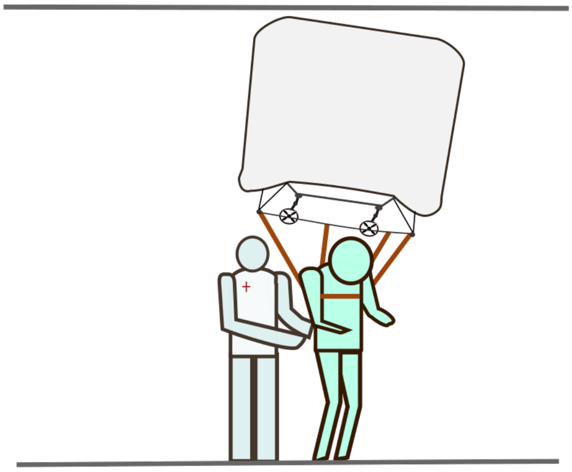

Figure 8: Assisting Pantients

Partly impaired can profit from more dynamic, proactivity granting treatments, not confined to preconfigured areas, even outdoors bipedal excursions are conceivable, depending on the patients capabilities. Ideally, such patients are granted a degree of indepence from any nursing personnel.

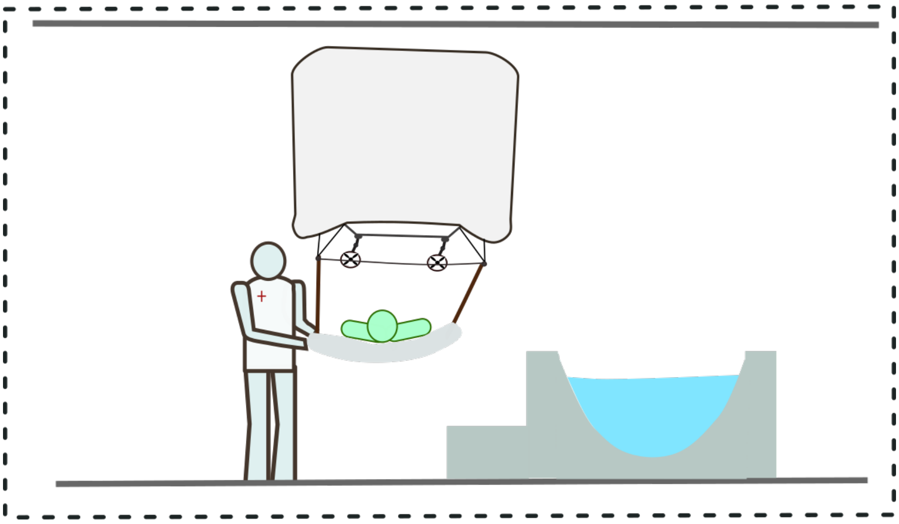

Figure 9: Fully Impaired Pantients

The second scenario underlines the value of LTA for Health care personnel of any kind: a versatile, surroundings agnostic mannouverability improvement for wiing intensive tasks during handling more severly impaired patients. Existing specialized equipment for surpassing similar challenges is often confined to overly adapted surroundings. LTA technologies can bring similiar handling advantages to a broader set of environments without requiring signifcant infrastructure adaptions to medical sites at all.

Industrial Engineering

Already conceived automatic UAV based delivery engines [Digital(2018)] can profit from a complementation effect through extenting its carriage spectrum by the superios load taking capabilites LTA offers.

When the last mile coverage was taken up by LTA UAVs, then even traditional delivery pipelines can be alleviated by rendering those more efficient [Langston(2017)].

Another autoamtic LTA technoloy application in the infrastructure maintenance automation, similarly to what was shown in the crafting section yet in another, less generic, but therefore to a more systematic, stricter automated degree since of the more streamlined, homogeneous surroundings to expect.

REFERENCES

[Digital(2018)] SINTEF Digital. Salmon delivered by hyperloop and mail by drone?, 2018. URL https://phys.org/news/2018-05-salmon-hyperloop-mail-drone.html.

[Khoury(2012)] G.A. Khoury. *Airship Technology*. Airship Technology. Cambridge University Press, 2012. ISBN 9781107019706. URL https://books.google.de/books?id=SiaejBco6NUC.

[Langston(2017)] Jennifer Langston. Drone vs. truck deliveries: Which create less carbon pollution?, 2017. URL https://phys.org/news/2017-05-drone-truck-deliveries-carbon-pollution.html.

[O'brien(2018a)] Matt O'brien. Maker of fearsome animal robots slowly emerges from stealth, 2018a. URL https://phys.org/news/2018-06-maker-fearsome-animal-robots-slowly.html.

[O'brien(2018b)] Matt O'brien. Boston dynamics' scary robot videos: Are they for real?, 2018b. URL https://phys.org/news/2018-06-boston-dynamics-scary-robot-videos.html.

ACRONYMS

LTA Lighter Than Air - technology principle. 3, 5, 6, 9–12, 14

UAV Unmanned Aerial Vehicle - small scale, nowadays prevailing airborne drone technology. 2, 3, 5