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Equipment to tag, track and collect biopsies from whales and dolphins: the ARTS, DFHorten and LKDart systems

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Abstract

Of all animals considered subjects for instrumentation for behavioral or physiological studies, cetaceans probably represent the greatest challenge to the engineer and biologist. The marine environment being harsh to electronics, evasive behavior during tagging approaches and the short time window available to attach instruments, all imply a need for innovative tagging solutions to facilitate better understanding of their life cycle, migration, physiology, behavior, health and genetics. Several animal-attached tag packages holding specific data loggers, e.g., time depth recorders, position, orientation, acoustic and video recorders for short to medium term studies, as well as tags developed for large scale migration telemetry studies are available as off-the-shelf devices, or in many cases as custom made sensor packages. Deployment of those instruments is often the limiting factor for data collection. The Aerial Remote Tag System (ARTS) is a flexible system which can easily be adapted to deploy different tag sensor packages and biopsy collection devices. This paper presents the history and design of the ARTS, and accessories developed for instrumentation and biopsy sampling of cetaceans, such as the recent developed ARTS–LKDart for biopsy sampling. Deployment of archival tags usually requires radio tracking of the instrumented animal, or at least tracking of the tag for recovery. Thus, we also here describe the automatic digital signal processing radio direction finder, the Direction Finder Horten (DFHorten unit).

Keywords: ARTS, DFHorten, Tagging, Telemetry, Tracking, Behavior, Cetaceans, Biopsy

Background

When direct observation of biological processes is not feasible, the use of animal-attached sensor packages, ranging from fine-scale sampling data-loggers to large-scale telemetry tags using satellite technologies, is required to add to our knowledge of the life of marine mammals [1, 2], including our understanding of the physical environments they inhabit [3–6]. Deploying tags efficiently and having the right tools to enable reliable tracking and device recovery are needed to conduct such research. Vessel and staff time to conduct research on free ranging cetaceans is often expensive, thus optimal field-tools are vital for the cost efficiency of marine mammal projects.

The ARTS (Aerial Remote Tag System) was first developed in Norway in 1997 by LKARTS-Norway and Restech Norway AS, for the Institute of Marine Research (IMR, Norway) to deploy radio tags on minke whales. During the following decades several research groups have adapted this pneumatic launcher system to their marine mammal research projects, involving deployments of invasive anchor tags as well as non-invasive suction-cup tags, and for remote collection of biopsy samples. Thus, the ARTS has become a well-tested and established tool for deployment of tags and biopsy darts for cetacean research. Most research groups using the

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ARTS, work within satellite telemetry projects deploying satellite tags [10, 13–15, 18–38]. In addition, the ARTS launcher has been used to deploy larger sensor packages (DTAG, Ctag and HVTag) since 2009 [9–14], as well as in projects using only light weight VHF tags [15]. To conduct controlled exposure experiments in behavioral response studies [14, 16, 17], there is a need for real-time tracking of focal animals to place a sound source in a specific location to conduct carefully designed exposures to tagged whales. In this type of field study, it is vital to know, where the tagged animal is relative to the source, which is facilitated using the automatic digital radio direction finder DFHorten.

A combination of careful planning, effective research tools, and a team with the right training are key factors for successful field work [39]. The scope of this paper is to demonstrate improved tagging techniques for instrumentation of whales and dolphins with the use of the tagging system ARTS, and to demonstrate tracking abilities in using the automatic signal processing radio direction finder, the DFHorten unit. In addition, we present a simultaneous tag and biopsy setup, and a new biopsy system, the ARTS–LKDart.

Methods

The ARTS system—development and design

The whale tag launcher ARTS has become an international field tool and tagging method in research projects working with telemetry and behavior studies of whales and dolphins ($n = 52$, as of March 2022). During the past 10 years ARTS have also been delivered to end-users with tagging-related accessories in a complete ARTS package ($n = 15$) including a specific design for the deployment of larger archival tags (Fig. 1B, C).

The first design of the launcher was built during winter 1997 and was followed up with laboratory testing the next year, resulting in the first ARTS ready for field tests (Figs. 2A, 3). The ARTS launches an arrow (carrier) with a grip designed to hold the tag during the flight, and then releases the tag upon attachment to the animal. The grip is specially customized for each tag type. In collaboration with Villum Jensen (Denmark), the first ARTSCarrier

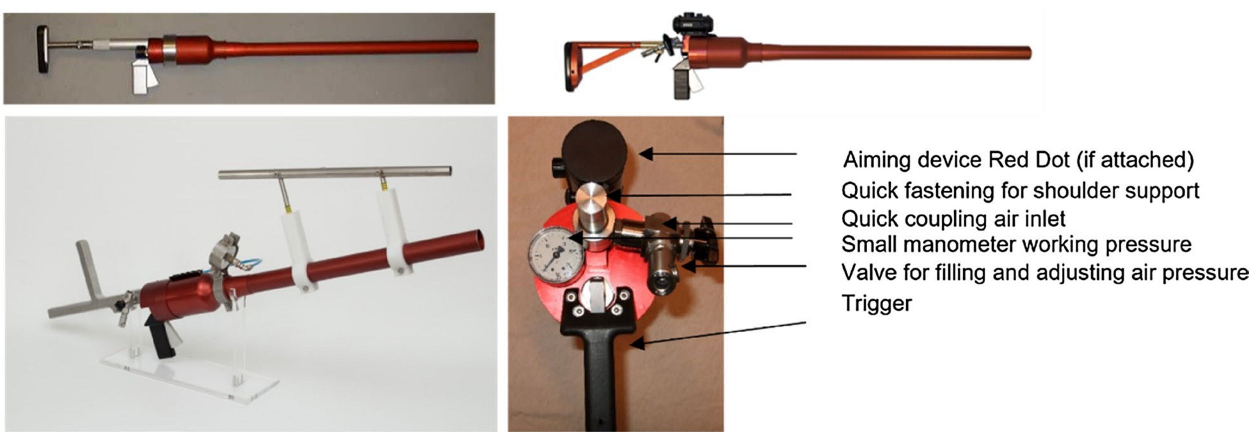

Fig. 1 Upper left panel shows an early prototype of the ARTS (2004) and upper right panel shows an ARTS model for deployments of satellite tags (ARTS-S, 2007). The ARTS model for deployments of larger sensor packages (ARTS-D, 2012) with an offset sighting bar is shown in lower left panel, while details of the main components on the ARTS housing, with the valve function, pressure control (small manometer), trigger and standard aiming device (Riflescope ZOS), is shown lower right panelPhoto by Tom Are Mathisen

Fig. 2 Early prototype of the ARTS (1998), left panel and the ARTSCarrier, with a Galvanic Time Release line (1998), right panel. Photo by Tom Are Mathisen and Lars Kleivane

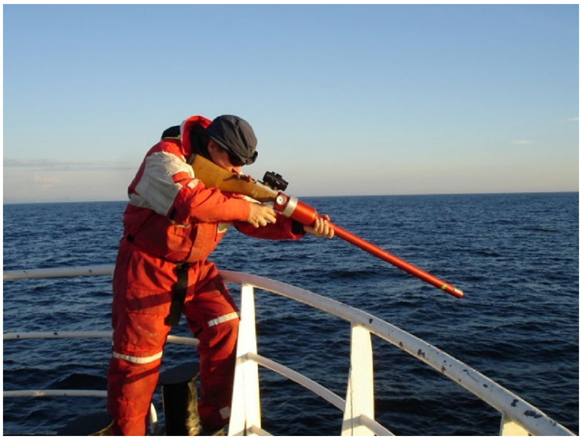

Fig. 3 Here is a typical ARTS setup from the bow of a larger vessel with an elevated platform, often used when deploying satellite tags to baleen whales. Photo by Paul Ensor

Fig. 4 Standard ARTS (ARTS-S) kit with 2 barrels (840 mm), one small pressure bottle with a reduction valve and a 2, 5 m long pressure hose, one aiming sight (Riflescope ZOS), and the ARTS pressure chamber (lower right), a quick shoulder shaft and a quick connector to the pressure tank. Photo by Tom Are Mathisen. Rev2

(Fig. 2B, ARTSC) was developed for a bowhead whale project in West Greenland [40], and the following years further development resulted in a variety of different ARTS carriers and accessories with diverse applications, all unique and adapted to the shape and size of each sensor-tag for optimal flight performance.

The basic function of the ARTS is to deploy the instrument to the target (whale or dolphin) at launching distances from 5 to 20 m, and then release the carrier from the tag after attachment to the target. The ARTS is a pneumatic launcher, where launching pressure is adjusted (5–25 bar) depending on the total weight of the ARTSCarrier and tag package, the species and the expected distance to the target. Thus, the expected distance to a target during approaches of a specific species will guide the setup of ARTSCarrier and will often be custom designed.

In general, lower pressures are preferred to reduce the impact on the animal and the risk of damage to the tag packages—this is a trade-off during deployment optimizing precision to a specific range.

During tagging approaches target species may be more or less evasive, keeping the tag boat at a distance—though whales may be more approachable in feeding and socializing contexts. For most species in any context, a boat approach within 20 m is likely possible and the ARTS can be set up for tag deployments at 20-, 15-, 10- and 5-m ranges with different sensor-packages. A typical field setup for a tagging project would be using a small tag boat to approach the whale and deploy the tag; however, also sailing boats, larger vessels, helicopter and even deployment from shore are platform-options during ARTS tagging.

The ARTS is based on technology owned by Restech Norway AS and is a reconstruction of a PLT® line thrower [8]. The stock resembles a shotgun stock (Fig. 2A), where the air-fill handle enables the tagger to choose the launching pressure (Fig. 1D). The air-fill handle is a two-way valve, allowing the filling or release of air from the pressure chamber. The air-fill handle can be constantly connected to the pressure tank (Scuba tank) on a fixed platform using a long flexible high-pressure hose attached to the quick coupling on the unit. In some cases, a smaller air tank carried along side, or in a backpack setup, is convenient if the tagger position needs to be flexible. In these cases, the hose can also be disconnected from the ARTS, since the valve has a closing function. The standard barrel dimension is 38 mm in diameter and 840 mm long; however, custom-made barrels are available (diameter: 12 mm to 90 mm), with variable length. A complete ARTS package (ARTS-SD) includes a standard ARTS (ARTS-S, Fig. 4) setup for satellite tag deployments (Fig. 1B) and an aiming bar for the launching of larger sensor packages which have a hyperbolic trajectory and need a different aim device and shaft (ARTS-D) (Fig. 1C).

ARTS deployment of satellite tags

In telemetry projects using satellite tags the original ARTS carrier (Fig. 1B) is a commonly used setup [15, 18, 27, 31, 46]; however, other carrier systems have been developed in the last decade [20, 23, 47]. The original ARTSC has been modified to a variety of satellite tag molds. The ARTSC standard is 650 mm long, with a body of Polypropylene (DURAPIPE superFLO ABS 32 mm PS EN ISO 15493), an outer diameter of 32 mm and inner diameter of 28 mm, and three polycarbonate steering fins of (Lexan 0,8 mm) attached with flexible Flex-Master glue (Partsmaster, USA). It is a simple carrier, easy to handle

Fig. 5 Use of different ARTS-Carriers when deploying satellite tags, shown in upper left panel(ARTSC) with GTR release line, a satellite tag from Wildlife Computers (SPOT5 mold 177) and anchor from IMR (Institute of Marine Research, Norway); upper right panel (ARTSC1) a setup with the same satellite tag but with different carrier design, with an anchor from NRISFS (National Research Institute of Fisheries Science, Japan); in middle left panel the ARTSLC for the Wildlife Computer LIMPET Tag SPLASH 292, anchors from Wildlife Computers not illustrated. In lower panel the ARTSTBC, a tethered system including a biopsy tip, for Wildlife Computers tags SPOT303/SPLASH302. Photos by Lars Kleivane

and easy to use. Other carriers have been developed for Type C tags/implant tube tags [39], while the latest ARTSTBC is designed for both Wildlife Computer SPLASH 302 and SPOT 303 tags (Fig. 5D). This tethered ARTS-carrier is especially designed for deployments up to 20 m, typically for approaches from larger vessels. It is designed with an integrated physical stopper to utilize increased pressures giving greater accuracy, while simultaneously collecting a biopsy sample. For many projects a tethered system is preferred, where the tag can be easily recovered if the deployment is unsuccessful in a miss or a bounce off the whale. Especially the latter can result in the loss of tags if the safety line is not used, since the carrier does not float with a larger satellite tag still attached. Another ARTSC system for lighter tags (WC; SPOT5 mold 177) is adding a galvanic timed release (GTR) mounted on a string between the tag and the carrier (Fig. 5A). In this setup, with the smaller satellite tag, the tag and carrier is floating, connected or if the tag detaches from the carrier. The ARTSC carrier, will stay along the tagged whale for some hours before GTR unit releases, and in most cases be lost. However, when operating at close range, the ARTSC can be deployed without any safety line, and thus recovered after deployment.

In 2015, LKARTS-Norway developed a carrier for the Wildlife Computer LIMPET tag SPLASH 292 (Fig. 5C). This carrier was specially developed for the off-range beaked whale study (ORBS) project studying Northern bottlenose whales [14]. This setup will also be equally useful for tagging other relatively small cetaceans, such as pilot whales, killer whales, minke whales, and beaked whales, or on larger whales, where it is desirable to deploy the tag to the dorsal fin.

ARTS deployments of archival tags

The start of the ARTS–DTAG carrier setup for the launching of a larger sensor package using the ARTS was conceived in 2006. Following 3 years of development and testing the ARTS–DTAGv2 setup, the LKCv2 carrier (Fig. 3C) became a fully operational system in 2009 [43]. We were then able to deploy DTAGs to killer whales at more than double the standard pole distances [43]. From 2012 a new and larger manometer (Fig. 6) was made an optional accessory for the ARTS, enabling finer control of the deployment pressure and hence better deployments.

In addition, several aiming devices have been tested to improve accuracy when using heavier tag systems with a hyperbolic curved flight (Fig. 1C; 7 left and right panels). Obviously, practice is vital and an important key for successful deployments, and today the preferred aiming system is the elevated aimbore system in the left panel of Fig. 7.

The launching of the tag and impact on the whales poses stress to the tag electronics and housing. We found that the G-forces when launching the DTAGv2 using the ARTS at 6–8 bar pressure at distances of 5–10 m, are well within the impact forces exerted during pole tagging. While the impact forces when ARTS-launching the DTAGv2 using 10–12 bar pressure at distances of 5–10 m are in the upper part of the forces measured during pole tagging. These tests were performed to ensure that the

Fig. 6 This figure shows a detail of the larger manometer setup (left panel) and a field view (right panel). Photo by Paul Ensor

Fig. 7 Two different aiming devices tested during the developpment of the ARTS–DTAG system. For heavy tags which will have a hyperbolic flight trajectory either a elevated aimbore (Left panel) or an aimpoint (Right panel) can be used. Photo by Christopher Hinchcliffe

risk of tag damage or impact on the whale were not significantly greater when deploying the DTAGv2 using the ARTS compared to the well-established method of deploying the tags with a long handheld pole (Fig. 8) [43].

Field results from 2009 showed that DTAGs launched with 7–8 bars pressure at 9–12 m range gave the highest success rate, especially when working with killer whales, and the average tag on whale time (TOWT) for ARTS deployed tags were comparable to TOWT using the pole system [43].

During the development of the ARTS–DTAG setup a rugged version of the DTAG housing was built at WHOI (Woods Hole Oceanographic Institution, USA) and the ARTS carrier was modified to soften the impact of the tag on animal. During cruises in Norway, Iceland and Brazil in the period from 2009 to 2020 the ARTS launcher was successfully used to deploy DTAGs on pilot, killer, northern bottlenose, sperm, minke, Bryde's (*Balaenoptera brydei*), sei (*Balaenoptera borealis*), fin (*Balaenoptera physalus*), blue (*Balaenoptera musculus*) and humpback whales (*Megaptera novaeangliae*) [9, 11, 12, 14, 43–45].

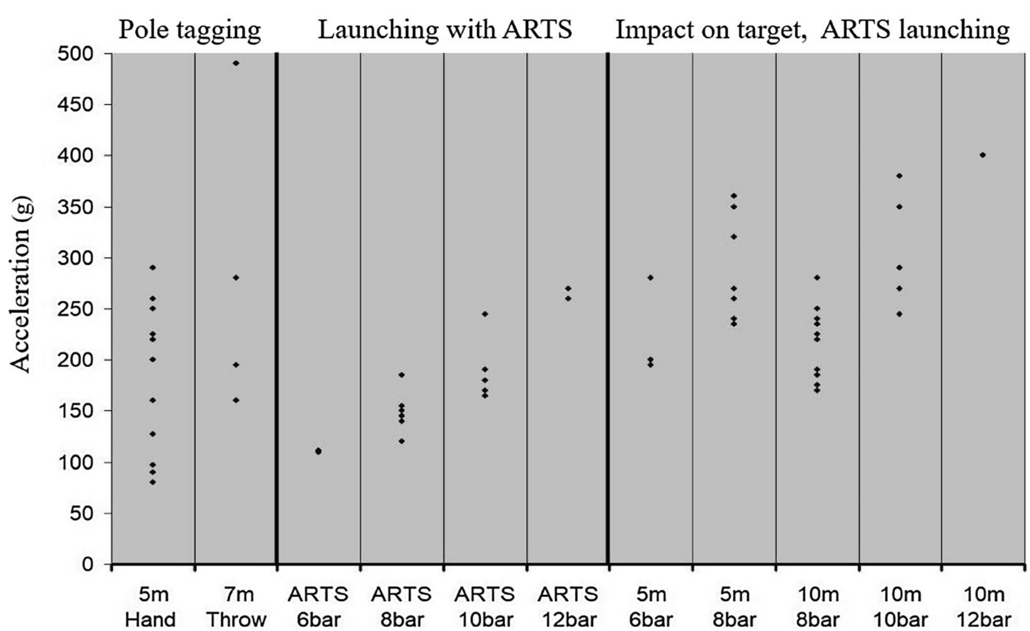

Fig. 8 Stress tests on DTAG electronics during deployment from two different tagging systems (Handheld pole and ARTS). Stress is measured as acceleration or deceleration (g) using an accelerometer placed on a dummy tag representing the electronics of the DTAGv2

Table 1 Overview of operational ARTS, carrier systems and biopsy darts

System	Carrier	Year	Testing	Tags
ARTS-S	ARTSC1	1997		Wildlife computer satellite tag; mold177
ARTS-S	ARTSC2	2001		Advanced telemetry systems VHF tag; MM100 Series
ARTS-S	ARTSC3	2012		LKARTS-Norway archival tag; Ctag
ARTS-S	ARTSLC	2014		Wildlife computer satellite tag; LIMPET SPLASH292
ARTS-S	ARTSLBC1[a]	2017		Wildlife computer satellite tag LIMPET SPLASH292
ARTS-S	ARTSTBC2[a]	2020		Wildlife computer satellite tags; SPOT303/SPLASH302
ARTS-D	LKCv2	2009		Woods hole oceanographic institution archival tag; DTAGv2
ARTS-D	LKCv2b	No	2011	DTAGv2 with barb attachment, not operational
ARTS-D	LKBCv2[a]	2012		LKARTS-Norway archival tag; HVTag
ARTS-D	LKCBv2[a]	2014		Sea mammal research unit archival tag; MixedDTAG
ARTS-D	LKCBv3[a]	2015		Univ. of Michigan?? Archival tag; DTAGv3
ARTS-D	LKCv2	No	2015	LKARTS-Norway archival tag; HVCamTag, not operational
ARTS-D	LKCBv2[a]	2021		Sea mammal research unit archival tag; MixedDTAG+
ARTS-S	LKDart10	2012		LKARTS-Norway biopsy dart
ARTS-S	LKDart21	2021		LKARTS-Norway biopsy dart

[a] Carriers including a biopsy part with biopsy tips from CETA-Dart (Finn Larsen, Danmark)

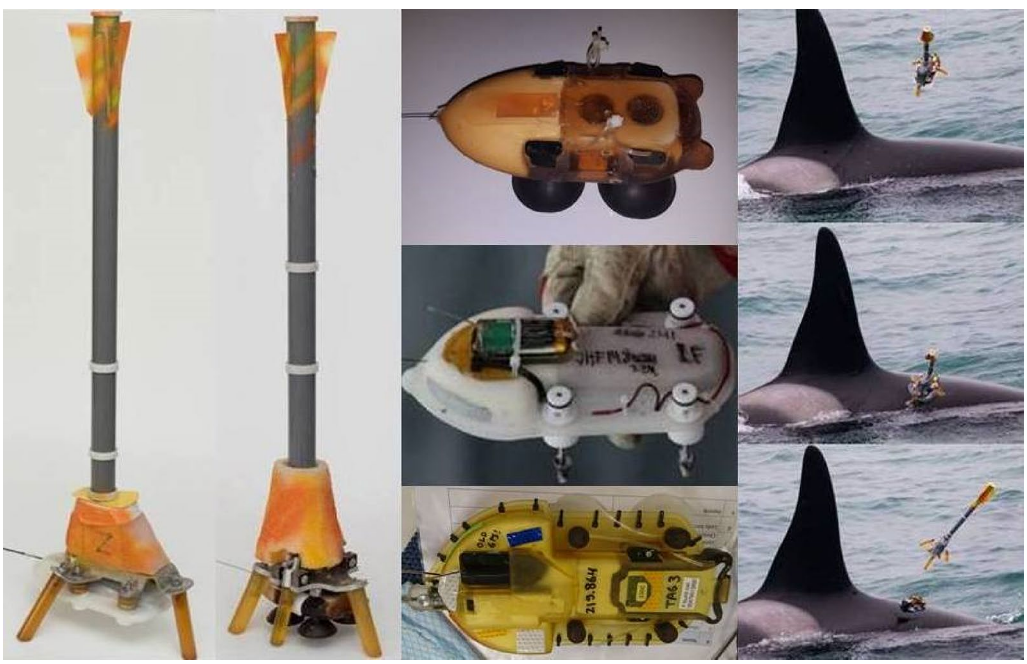

Fig. 9 Several sensor packages have been adapted with specialized carriers. In left panel the LKCv2 with the DTAGv2; next panel the LKCv3 with the DTAGv3; the middle panels from the top show the DTAGv3;middle panel with the DTAGv2b with barb attachment and in the lower panel a Sirtrack FL2 (GPSFastlock) mounted on the top of a Mixed-DTAG. The right panels show an example of the ARTS–DTAG system using a LKCv2 deploying a Mixed-DTAG+ on a killer whale. Photo by Tom Are Mathisen, Lars Kleivane and Nicholai Xuereb

At present the basic ARTS carrier, LKC, is operational with several archival tags (Table 1). Some of these tags (DTAGv2 and DTAGv3) are shown in Fig. 9, with their respective specialized carriers the LKCv2 and LKCv3. For the details of various setups with tags and carriers we refer to field reports and publications [7, 9, 11, 12, 41–43, 48–53].

ARTS and biopsy darts

The LKDart was developed during 2010 to able to take biopsy samples through the blubber layer of large cetaceans. These darts are launched with the ARTS system, typically using biopsy tips from Finn Larsen (CETA-dart, DK). In 2010 the LKDart was successfully tested using variable biopsy tips with length from 20 to 80 mm, and the ARTS–LKDart biopsy system was operational from 2012 [56, 57]. In Fig. 10 is shown the LKDart, with the 2010 and the 2021 versions, and details of the tip attachment as well as a sample collected with an 80 mm biopsy tip (Fig. 10B). Furthermore, the LKTDart (Fig. 10C) a tethered (25 m) dart setup designed especially for use from larger vessels was functional as of 2017.

In 2012 a design of a system to enable the collection of a biopsy sample simultanously with the deployment of DTAGv2 was initiated. Today, this setup using the LKBC carrier is operational, and can be seen in Fig. 11A. A recent design of the ARTSLC (for LIMPET tag deployments), also includes a simultaneous biopsy collection. This carrier, now named ARTSLBC, was operational from 2017 (Fig. 11B).

Fig. 11 Left panel the Mixed-DTAG deployed to a humpback whale. Right panel a LIMPET tag (WC, SPLASH 292) deployed to a bottlenose dolphin (*Tursiops truncatus*). Both simultaneously collecting a biopsy sample. Photo by Christopher Hinchcliffe and Leonardo Wedekin

DFHorten—a digital signal processing radio direction finder unit

An increasing number of the tags deployed with the ARTS system are archival tags in projects using controlled exposure experiments to study changes in whale behavior, where it is vital to follow and track the tagged whale. The signal processing radio automatic direction finder, the DFHorten unit (Fig. 12A, $n = 17$ as of March 2022), was developed for this purpose, to make it possible to track and follow VHF signals and thereby visually record positions of a focal tagged whale, collect relevant environment data, presence of conspecific and interspecific animals around the focal tagged whale, as well as social behavioral data. Other real time tracking devices available have been a single yagi antenna connected to a receiver, or then more recently the development of Fast-LockGPS technology, where satellite signals assembled directly on antennas are processed near real time and further visualized on a chart [95].

The DFHorten is a tracking device, connected to 4 Yagi antenna elements pointing in 4 different directions 90° apart (Fig. 13A–C), and further connected to a speaker and a radio receiver [57]. The unit has a front panel with LED lights in a circle with 24 red diodes (15 degrees between diodes), and a cross of 9 red diodes on each cardinal direction (Fig. 12B, C). The four antennas are connected to separate channels and the DFHorten unit switches between the four channels within a 16 ms cycle. The signal strength of the two channels receiving the weakest signal is discarded and the signal strength of the two channels receiving the strongest signals are weighted in a digital processing chain. The best estimate of direction is indicated with 15° resolution on the outer diodes (Fig. 12B, C). The signal strength on all four antennas is shown on the LED cross. To indicate an incoming signal the centered LED will flash, indicating that you have had a good signal reception. For optimal performance 2–4 pulses per surfacing are required. However, multiple, longer and stronger VHF pulses would increase the range and performance of the DFHorten unit. The DFHorten functions well with the radio receivers ATS

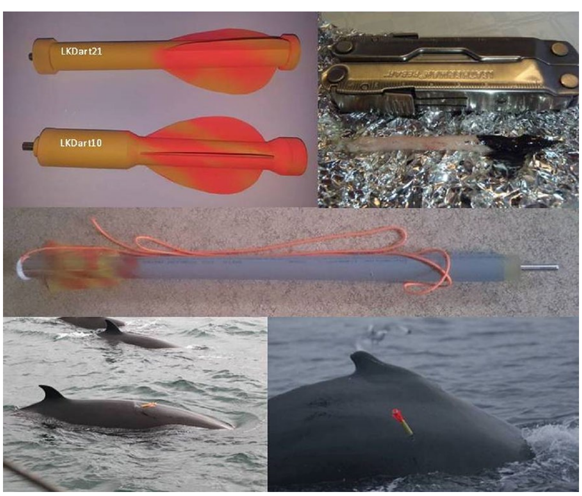

Fig. 10 LKDart21 and LKDart10 (upper panel left). Upper panel right shows a blubber sample collected with a Finn Larsen biopsy tip, 80 mm long. Middle panel show the tethered setup for the LKDart, the LKTDart, while lower panels demonstrate biopsy sampling of a northern bottlenose (left) whale and humpback whale (right), using the LKDart10. Photo by Lars Kleivane and Saana Isojunno

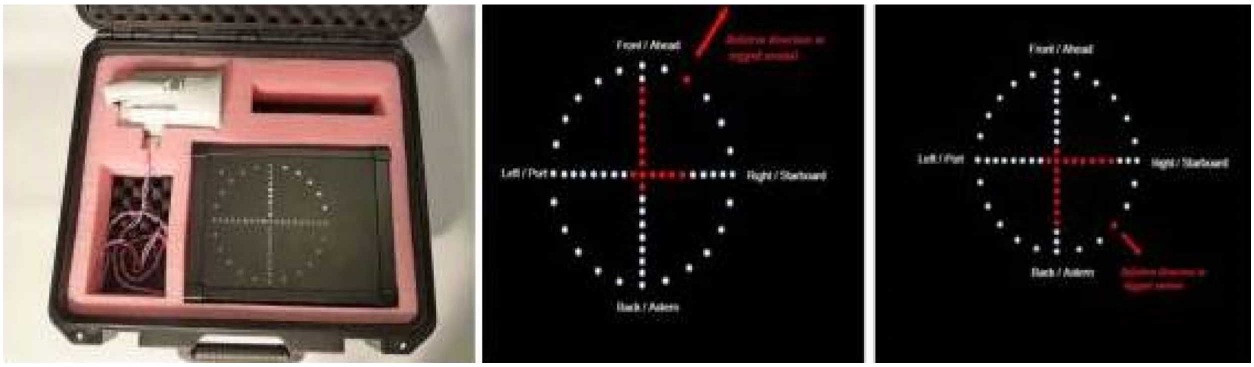

Fig. 12 In the left panel the DFHorten kit is shown in detail with a speaker, cables for 12 V connection, the DFHorten unit, and space for an R-1000 receiver (Communication Specialist, Inc., USA). The following panelsshow examples of the directional display of the DFHorten unit. Photo by Lars Kleivane

Fig. 13 This figure shows a tracker and tag boat (upper left panel) with the DFHorten rigged in a weatherproof box ahead of the front glass and with 4 5-element Yagi antennas. In this setup the weather box can be regulated, so that the upper bridge and the cabin can read the DFHorten output. In right panel the antenna rig is at the top of a sailing boat mast, including both antenna frequencies for the DTAGv2 (148 MHz) and the DTAGv3 (219 MHz). In lower left panel the antenna rig is at the bow of a larger vessel. Photo by Lars Kleivane

2000 (Advanced Telemetry Systems, USA) and the R-1000 (Communications Specialists Inc., USA). The advantage of using the DFHorten becomes evident in poor weather or when it is dark, as well as during recovery of a floating tag. With a good and high tag placement on a target whale, the DFHorten unit is operational to a about 2 nm depending on the antenna height and electromagnetic noise of the platform [7, 9, 11, 12, 16, 17, 44]. The pulse length and strength of most VHF beacons are short and weak, in addition the processing of the DFHorten is draining energy from the signal, resulting in a significant shorter operational modus than if using a single yagi antenna directly with the radio receiver. However, in most settings for a focal follow, 2 nm will be sufficient to obtain a reliable tracking of the tagged whale. For detailed description of the DFHorten unit we refer to the manual [57]. We are currently in the testing phase of using the DFHorten box also to apply to satellite tag signals, thus being able to track satellite tagged whales and dolphins in real-time.

Results

Key outcomes

Several ARTS carriers and biopsy darts have been developed in the last two decades to enable use of the ARTS with different tags for different purposes (Table 1). In multiple studies the ARTS has been one of the principal tagging systems (Table 2). In addition, in parallel different carriers have been modified and/or developed in various projects [13, 51, 59, 94].

A conservative estimate of 11 baleen whale species (minke, humpback, Bryde's, sei, fin, blue, pygmy blue (*Balaenoptera musculus brevicauda*) grey (*Eschrichtius robustus)*, bowhead (*Balaena mysticetus)*, North Pacific right (*Eubalaena japonica)* and southern right whale (*Eubalaena australis)* and 7 odontocetes species (common bottlenose, white-beaked (*Lagenorhynchus albirostris)*, long-finned pilot, killer, northern bottlenose, Baird's beaked (*Berardius bairdii)* and sperm whale] have been tagged with the ARTS system worldwide (2022). Key scientific publications, where the sampling of data has been attained using the whale tag launcher ARTS, the processing radio direction finder DFHorten and or the biopsy setup ARTS–LKDart, are presented in Table 2.

We outline the study on killer whales [12], northern bottlenose whales [14, 16] and minke whales [17], since these species are relatively difficult to tag. The DFHorten unit was a key tool for successfully completed controlled experimental exposures as part of these studies [14, 54].

Table 2 Overview of species and publications from several studies using the ARTS system

Species	Telemetry projects using satellite tags Reference number of publication	Behaviour studies using archival tags Reference number of publication
Minke whale	[15, 18, 41, 58]	[7, 9, 15, 43]
Bryde's whale	[44]	[44, 45]
Sei whale	[22, 31, 44, 45, 75, 77, 78, 93]	[44, 45]
Grey whale	[19, 87, 88]	
Fin whale	[69, 75, 79– 82, 93]	[13]
Blue whale	[18, 23, 34, 38, 69–76, 93]	[13, 54]
Pygmy blue whales (Balaenoptera musculus brevicauda)	[23]	
Humpback whale	[21, 23, 24, 27, 28, 30, 32, 59–68]	[7, 9, 44, 51, 53]
Bowhead whale	[25, 35, 36, 40, 83]	[51]
North Pacific right whale	[84]	
North Atlantic right whale	[59]	
Southern right whale	[47, 85, 86]	
Bottlenose dolphin	[44, 45]	
Long-finned pilot whale		[11, 52, 53]
Killer whale	[33, 45, 91]	[11, 12, 42, 43, 52]
Northern bottlenose whale	[14, 16, 54]	[14, 16, 54]
Sperm whale	[89, 90]	[13]

Results from ARTS deployments of LIMPET tags reveal a mean tag on whale time (TOWT) for killer whales of 47 days ($n = 12$), with the highest TOWT of 103 days [33]. Although few LIMPET tags were involved ($n = 8$), the TOWT on northern bottlenose whales was comparable when comparing deployments using the ARTS with the Dan-Inject system [54]. During the PMC-SB (Projecto de Monitoramento de Cetaceos na Bacia de Santos) project in Brazil the same carrier including a biopsy tip (ARTSLBC) with deployments on common dolphin, killer, sei, Bryde's and fin whale resulting in TOWT from 1 to 38 days [44, 45].

The IWC paper SC/60/PFI 8 [15] demonstrates the power when combining research tools as the whale tag launcher ARTS and the radio direction finder DFHorten unit. This effective combination of tools is also well-documented in the Body-Condition, 3S1 and 3S-ORBS projects at Jan Mayen [14, 16, 54].

The ARTS–LKDart system is well-demonstrated in an Icelandic project, where more than 70 biopsy samples of killer whales were collected [55, 56], while the carriers LKBCv2 and the ARTSLBC are still in process and are at present collecting a biopsy sample at roughly 50% of the deployments hitting the target [16, 45].

Conclusions and discussion

The whale tag launcher ARTS is today a worldwide tagging system operational in telemetry projects using satellite tags and in field operations deploying archival tags. As a pneumatic launcher, it is the only existing system enabling deployments of archival suction cup tags, as well as implant type C tags; however, other existing deployment systems are available. Especially for archival tags as DTAGs, the well-established pole tagging system is widely used both directly as in a handheld setup or then in a cantilever long-pole setup, the later adapted especially to larger target species. Also, certain project is using pole tagging methods when deploying satellite tags, while other projects are using the Dan-Inject pneumatic system or cross bow for the deployment of lighter satellite tags such as the Limpet tag [96, 97]. Relative to the DFHorten tracking system, there are no comparable systems as today; however, there are a number of alternative tracking methods like a handheld setup with a single yagi antenna connected to a radio receiver. This setup has a superior and better range; however, without directionality, and mostly this setup signalizes when the tagged animal is at the surface to enable scanning and a visual sighting. A tracking system using the Goniometer in a direct reception of satellite tag signals holding FastLock GPS information, is currently being tested in a 3S project [95], and if this is successful it will be a strong almost real-time tracking system in the future. The LKDart was developed especially to enable longer biopsy samples, for projects studying components in the blubber layer (hormones, contaminants, etc.); however, other well-established biopsy systems are available, where the biopsy tip is maximum 40 mm. Especially the powder systems Larsen Gun [98] and the Paxarms [99] are widely used in projects sampling biopsies, as well as various crossbows [100, 101].

The aim of this paper was to highlight the history and use of the ARTS and its accessories as well as the processing radio direction finder DFHorten. Several ARTS-carriers have been developed during the last two decades to allow deployments of satellite tags and archival tags to whales and dolphins, all to better understand the complex of cetacean behavior and life cycles and collect oceanographic information [5] that is urgently needed for an improved understanding of climate and ocean variability. Due to the greater tagging range when deploying archival tags compared to standard hand pole deployments, the ARTS system has proven to be an efficient tool, and is particularly useful in projects studying fast moving animals that are difficult to approach by a tag boat.

Standard operational ARTS modus when launching archival tags (300–500 g) such as DTAGv2 or HVTag should be in the range from 7.5 to 9.5 bar, often using 8.8 bar at ranges of 12–14 m. For the DTAGv3, which is a smaller tag, the pressure would be 1 bar lower, while for heavier tags (e.g., Mixed-DTAG) the pressure range would be from 8 to 11 bar. For satellite tags with a total weight from 300 to 700 g, the launching pressure should be in the range from 10 to 24 bar depending on species, the range, carrier- and anchor design. When deploying tags at a range of 10–15 m the pressure should be from 12 to 18 bar, while for sperm whales about 5 bar more due to their dense blubber layer. For the lighter Limpet satellite tags, recommended launching pressure out to 10 m and 15 m are at 9 bar and 11 bar, respectively. When using the ARTS–LKDart setup at very close range < 7 m the barrel pressure should be 6 bar, while at ranges out to 12 m and up to 20 m the standard launching pressure should be 6–8 bar and 8–10 bar, respectively. For longer ranges exceeding 20 m the recommended launching pressure is 10–12 bar.

Note that these are only recommendations, and that each project is responsible for the safety of people, animals and equipment. Stay safe and trust your research tools by training and practice.

Abbreviations
ARTS: Aerial remote tag system—a pneumatic whale tag launcher; ARTS-S: ARTS satellite; ARTS-D: ARTS datalogger; ARTS-SD: ARTS satellite and datalogger (complete ARTS package); ARTSC: The original carrier for ARTS deployments of satellite tags; ARTSTBC: The tethered ARTS carrier for Wildlife Computer tags in the 300 series, with simultaneous biopsy sampling; ARTSLC: The ARTS carrier for LIMPET satellite tag (SPLASH 292) from Wildlife Computer; ARTSLBC: The ARTS carrier for LIMPET satellite tag (SPLASH 292) from Wildlife Computer with simultaneous biopsy sampling; DFHorten: Directional Finder Horten—an automatic processing radio direction finder produced in Horten; DTAGv2: Johnson and Tyack [41]; DTAGv3: Miller et al. [16, 54]; HVTag: Horizontal and Vertical Tag, a suction cup tag including Wildlife Computer logger (TDR10-F-297C) and a VHF beacon (Advanced Telemetry Systems MM100 Series). The tag package size is similar to the DTAGv2. Kleivane et al. 2013; LKCv2: The ARTS carrier for deployments of DTAGv2, Mixed-DTAG and Mixed-DTAG+; LKBCv2: The ARTS carrier for DTAGv2, Mixed-DTAG and Mixed-DTAG+ with simultaneous biopsy sampling; LKCv2b: The ARTS carrier for DTAGv2 with barb attachment; LKBCv3: The ARTS carrier for DTAGv3 with simultaneous biopsy sampling; LKDart10: The biopsy dart for the ARTS system, developed in 2010; LKDart21: A new version biopsy dart for the ARTS system, 2021; LKTDart: The tethered biopsy dart for the ARTS system; Mixed-DTAG: Miller et al. [16, 54]; Mixed-DTAG +: Miller et al. [92]; 3S-project: Sea mammals and sonar safety project: international research project with the aim to investigate behavioral reactions of cetaceans to naval sonar signals, to establish safety limits for sonar operations.

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Author contributions
LK initiated and drafted the manuscript and PHK, PM, AB and NØ commented on text and figures, and edited the manuscript. All authors read and approved the final manuscript.

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Declarations

Ethics approval and consent to participate
During the development of the ARTS system, all the tagging effort was handled by experienced professionals under permits in respective projects and reported and published under these permits.

Consent for publication
Not applicable.

Competing interests
Lars Kleivane have mutual interest with Restech-Norway and ASJ Electronics to the systems ARTS and DFHorten, respectively.

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