HI JUNO: CONTACTING A PASSING SPACECRAFT WITH AMATEUR RADIO. P. Dyches[1], D. Goods[1], D. Kirchner[2] and W. Kurth[2]. [1]Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109, preston.dyches@jpl.nasa.gov and daniel.e.goods@jpl.nasa.gov, [2]University of Iowa, Dept. of Physics and Astronomy, Iowa City, IA 52242, donald-kirchner@uiowa.edu and william-kurth@uiowa.edu.

Introduction: NASA's Juno spacecraft flew past Earth on Oct. 9, 2013 for a gravitational boost that would send it toward a 2016 rendezvous with Jupiter. In the spirit of public engagement, the Juno mission invited amateur radio operators around the world to transmit a Morse code message in unison in the hope that Juno would be able to detect it. The successful outcome of this effort represents the first intelligent information sent by members of the public to a passing interplanetary spacecraft.

Background: Like many NASA missions, Juno has attempted to find innovative ways to generate public interest, including flying a set of Lego minifigures and producing a video series featuring Bill Nye the Science Guy. To celebrate the Earth flyby milestone, the Juno team sought an activity that would more actively involve the public. Three months before the encounter we focused on the potential for the passing spacecraft to detect signs of intelligent life with its radio and plasma science instrument, called Waves. Past experiments using radio recievers on the Galileo and Cassini spacecraft successfully detected shortwave radio transmissions during their Earth flybys, but they did not decode intelligent information from those signals [1].

Concept Development: Members of the Waves team (Kurth and Kirchner) indicated that while the instrument could not detect a coherent audio message, it should be able to pick out a transmitted pattern in Morse code, provided the signal was strong enough. The ionospheric refraction ham radio operators, or hams, normally depend on for long-range transmission would also need to be weak – a factor largely controlled by sunlight and space weather conditions.

The team settled on a very simple greeting, understood in many parts of the world: "hi." In Morse code, "hi" is represented as "…. .." (four dits, a space, and two more dits).

To create a clear pattern of Morse code dits via a combined transmission from thousands of hams required a webpage with simple, clear instructions and a bold visual indicator of when to transmit. The page was coded to read the system time on the viewer's computer and tell them when to "key down" to produce a dit, or "key up" to leave the radio channel silent.

The Morse code pattern would repeat every 10 minutes during the period when Juno was within 50,000 km of Earth (within an hour of closest approach). Hams would transmit each dit for 30 seconds, which is *extremely* slow by normal standards. This allowed enough time for transmissions to coalesce into an additive signal for each dit, given that participant's clocks were likely to be out of sync by at least several seconds.

The Waves team chose the frequency band of 28 MHz in order to get minimal refraction from the ionosphere – but hopefully enough to bounce signals from the U.S. (which would be below the horizon near the time of closest approach) to the spacecraft. The Waves receiver used for the activity (the HFR) has a bandwidth of 1MHz, and would sweep through the band once per second; in order to spread the energy over the detection bandwidth, hams were assigned a range of frequencies according to the last letter of their callsign. A list of headings was provided for hams using directional antennas.

The Waves team calculated that, in order to enable detection at 1db above noise level at 28 MHz while Juno was within ±50,000 km altitude, the minimum number of participants required would be around a thousand, assuming an average transmitted power of 100W.

Spreading the word: Once the event webpage was live, the Juno team sent a concise invite via email to major amateur radio organizations around he world. The intent was to include all necessary information on the event webpage and get the URL to as many hams as possible. In practice, amateur radio operators are extremely technically savvy – not unlike the amateur astronomy community – so it proved important to provide a thorough FAQ on the event page and to answer emailed inquries in a timely manner.

In order to enhance the event's appeal to and credibility with hams, the Juno team chose to offer QSL cards to participants. QSL cards are a type of postcard traditionally exchanged by hams in confirmation of radio contact. A few hams (and one reporter) expressed concern that the activity was asking hams to broadcast, which they are not allowed to do; hams can only engage in two-way communication. While the event webpage clearly indicated that participation should conform to local and national laws, the team responded to indicate that hams were being asked to transmit in a beacon mode (which is generally allowed) and that we would be confirming receipt of the signal, thus making it a two-way communication. The QSL cards thus helped to validate lawful transmissions to Juno.

Execution: The partial U.S. government shutdown that began on Oct. 1, 2013 caused several other planned public engagement activities for the Juno flyby to be canceled. Fortunately the "Hi Juno" webpage had been published in advance of the shutdown, and still functioned, although no updates were made to the page. Although the shutdown suspended the mission's social media, the JPL Juno team was able to email amateur radio organizations two days before the flyby to confirm that Juno would indeed be listening.

The Juno spacecraft successfully completed its flyby on Oct. 9, passing just 561 km above the coast of South Africa. The "hi" message was clearly detectable – three partial messages, three complete – above the noise in six of the nine, 10-minute periods from 1800 to 1920 UTC.

The activity was scheduled to take place from 1800 to 2040 UTC, but a safe mode entry by the spacecraft just after closest approach caused data collection by the science instruments to cease. Because of the safe mode entry, the Juno team was unable to receive transmissions from hams during the outbound leg of the flyby.

The Juno team received confirmations of participation requesting QSL cards from approximately 1500 hams, on every continent, including Antarctica. The two identical webpages created for the activity, hosted by JPL and Southwest Research Institute (SwRI), saw a total of ~24,000 unique visitors on Oct. 9. The discrepancy between the large number of visitors and the number of QSL requests is puzzling. It could be the case that many who participated did not email the mission to confirm.

Sharing the results: Following the flyby, the Juno Waves data were used to create a series of audio tones reproducing the transmitted Morse code message. The tones were presented in a video, alongside a spectrogram of the Waves data from the encounter. This public engagement product was created by Goods, who is an artist by training, from materials provided by the Waves team.

Goods and Dyches also produced a four-minute documentary video, featuring the hams, who describe their participation and react to the successful receipt of their message.

These products were shared by the Juno science team during a press briefing at the 2013 AGU Fall Meeting, along with other results that included an Earth flyby movie. The products and the SwRI version of the activity webpage are archived at http://missionjuno.swri.edu/hijuno.

Response to the activity from hams was overwhelmingly positive, with many emailing that they enjoyed taking part, thought it was a neat idea, and thanked NASA for directly involving them in the mission. Many sent photos of their radio equipment during transmission, or of the radio spectrum as they saw it during the activity. A few participants expressed that they found the long, slow pace of the message (1/25th word per minute) to be excruciating, although quite a few reported that they used software to control their transmissions and simply monitored their equipment as it sent the message sequence.

Lessons learned: The Hi Juno activity produced a fairly unique result at low cost to the mission. The JPL-hosted event webpage was designed to be very simple and easy to code and publish, and the same code was then ported to the SwRI mission website. The mini-documentary video was created by a director local to JPL at very low cost, and the cost to design, print, and mail 1500 postcards is quite low.

The impact of the Hi Juno story may have been lessened by including it in a larger press release. Nevertheless, the exposure provided by announcing the activity's success in the high-profile AGU venue might have more than made up for the loss of priority.

The data entry task of collecting 1500 mailing addresses for QSL cards from emails proved quite time consuming, and would have been better handled by providing a self-entry form on the webpage.

Only a couple of negative comments from participants were observed, most resulting from confusion about details of how to participate that were easily rectified via email. One notable complaint was posted on The Planetary Society's generally favorable blog about the activity [2], in which the ham said he felt "abused" by the Juno team's slowness in sharing the results and treatment of the activity as a "funny gimmick." While the team tried to clearly indicate that the purpose of the activity was for public engagement, it is not difficult to see how some participants might have gotten the idea that there was a greater scientific purpose behind it. Nonetheless, along with the rest of the data collected during the flyby, the Hi Juno activity did provide an interesting test of the Waves instrument, and was a useful exercise for both the science and public engagement teams as they look toward Juno's activities at Jupiter.

References: [1] Fischer G. and Rucker H. O. (2006) *Planetary Radio Emissions VI*, 299–306. [2] Lakdawalla, E. (2013) *www.planetary.org/blogs*, Conversations with an interplanetary spacecraft: "Hi, Juno!"