SHALL WE SEND HUMANS TO HOLDEN CRATER? HOW A GEODESIC GIS APPROACH CAN AID THE LANDING SITE SELECTION FOR FUTURE MISSIONS TO MARS. J.H.P. Oosthoek[1], P. Arriazu[2] and R. Marco Figuera[1], [1]Department of Physics and Earth Sciences, Jacobs University, Bremen, Germany (j.oosthoek@jacobs-university.de) [2]ETSIIT, University of the Basque Country, Bilbao, Spain.

Introduction: The stakes are high when it comes to sending humans to Mars. The scientific results of all past robotic missions need to be incorporated in to making the best selection of a landing site. It would therefore be helpful to encourage publishing data as open source. Geographical information system (GIS) software is a great tool to perform such spatial data analysis and can greatly reduce the number of potential landing sites [1].

Until recently, spatial analysis in a GIS was limited to 2D map projections. These projections are sufficient for local to regional scale studies. However, global scale spatial analyses, such as landing site selection, immediately show the limitations of 2D projections: -180°E equals 180°E. Therefore, a GIS is needed that projects the data on a sphere (or ellipsoid) and that can perform geodesic spatial analysis.

We present the first results of a geodesic-GIS approach to landing site selection for future missions to Mars. 10 types of potential regions of interest (ROIs) were selected as input [2-11] (Table 1). Holden crater (a Mars Science Laboratory (MSL) candidate landing site) proved to be the most promising [12] (Figure 1).

Methods and results: In general, landing site selection can be divided into 3 steps:

1. Define the areas where not to land.
2. Select a target outside of the excluded areas.
3. Investigate each target in high detail with respect to engineering constraints and science potential.

We discuss our approach to the second step and refer to the results of step one presented in [13]. Both steps have been performed using ESRI ArcGIS 10.2.

Step 2: As defined by the workshop conveners the various scientific and resource ROIs need to lie within 100 km of the landing site (e.g. the Exploration Zone (EZ)). All 10 ROIs we have used are based on scientific literature (Table 1).

Table 1. The 10 types of ROIs chosen for this study.

1. Deltas [2]	6. Dune fields [7]
2. Hydrous mineral sites [3]	7. Open-basin lakes [8]
3. Layered Megablocks [4]	8. Valley networks [9]
4. Infilled craters [5]	9. Tectonic & volcanic structures [10]
5. TES Exposed Bedrock [6]	10. OMEGA olivine [11]

For each ROI we created geodesic polygon buffers of 100 km. We used a 3396.19 km spherical representation of Mars. The buffer method only works with point data and lines, and polygons were converted to their vertex points [using: 14]. The olivine data [11] was provided as a raster dataset and was converted to a shapefile.

The 10 geodesic buffers were combined into one dataset using the Union ArcGIS tool [15]. For each ROI, the result contains a field that is set to either 0 (meaning that there is overlap) or -1 (meaning that there is no overlap). Figure 1 shows the color-coded results. Three areas were found to cover a maximum of 8 out of the 10 geodesic buffers. In other words, 8 of the ROIs are within 100 km distance to these areas (Figure 1). Of these three areas, Holden crater is the most promising. The other regions are mostly within the excluded areas determined in step 1.

Discussion and future work: Besides Holden crater also Eberswalde crater, 30 km north of Holden, falls within 100 km of our resulting area. Both craters contain deltaic deposits [2] and were in the top 4 of candidate landing sites for MSL [12]. Holden, Eberswalde and the surrounding region are relatively well covered by high resolution imagery (HiRISE [16]) and hyperspectral data (CRISM [17]) (Figure 2). These datasets have led to the detection of 3 [3,4,5] of the 10 ROIs. Potential targets, classified using our approach, are therefore expected to lie in the high density areas as seen in Figure 2.

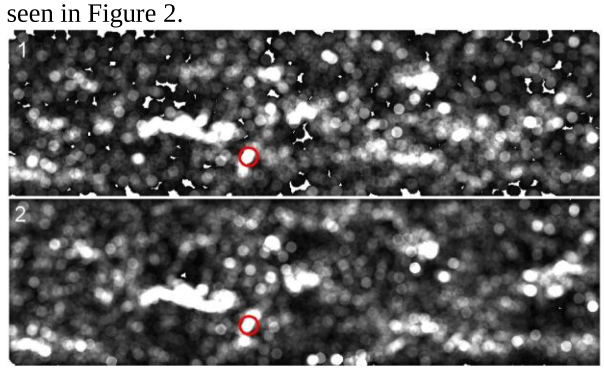

Figure 2. Density maps of HiRISE (1) and CRISM (2) data coverage, between -180°E, 180°E and within 50° N and S. White is high density. The red circle is the location of Holden.

Our approach is highly dependent on the quality of the input data. Although many datasets were available online [e.g. 18], some of the coordinate data had to be extracted from the respective publication. The approach would therefore greatly benefit from the open source publishing of scientific GIS data.

We currently weighted each ROI type as equally important. More elaborate evaluations than simple counting can be devised. Tools used for mineral exploration on Earth, such as the Spatial Data Modeller ArcGIS plugin [19], are of interest but would need to be redesigned to allow for geodesic spatial analysis.

Instead of buffers we could use an intersection method to count the number of ROIs within each EZ. We plan to use the Near tool [20] of ArcGIS 10.2, which supports geodesic distances. Alternatively, we may upgrade to version 10.3, which supports geodesic intersections [21].

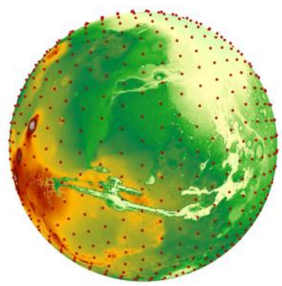

Figure 3. Example of a geodesic grid of points on the Martian globe (made using ESRI ArcGlobe and color coded MOLA data).

To classify each potential landing site, we will use a geodesic grid of points, created using the Delaunay triangulation method [22, 23] (Figure 3). Each point reflects a 25 km^2 circle (the area of the landing site as provided by the workshop conveners).

In conclusion, our ROI selection approach is a work in progress and needs to be further refined. We encourage scientists to share their data, especially global datasets of potential ROIs for a future human mission to Mars.

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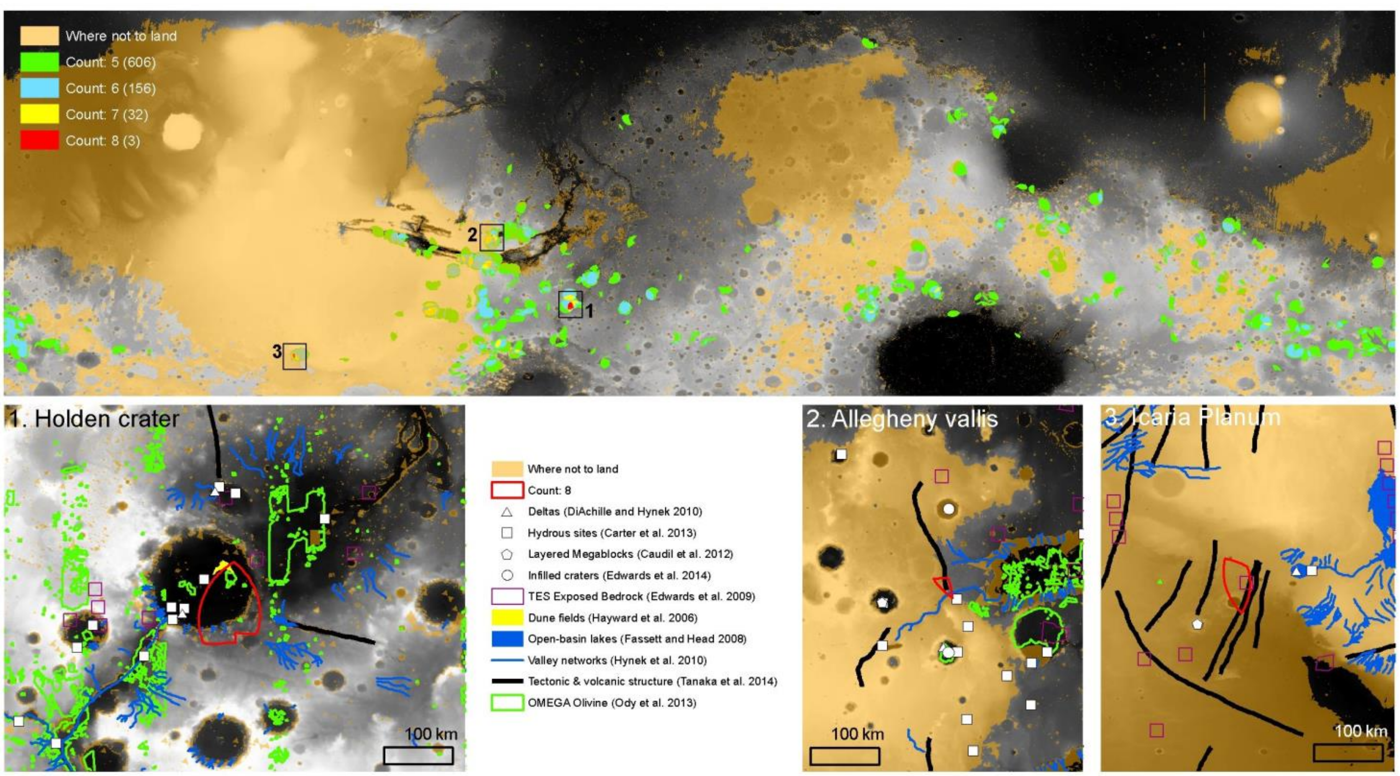

Figure 1. The preliminary results of the geodesic buffer approach. Only areas with 5 to 8 ROIs within a 100 km radius are shown. Areas within a 100km radius of 9 or 10 ROIs were not detected. For a further explanation see the text. The background is grayscale Mars Orbiter Laser Altimeter (MOLA) data.