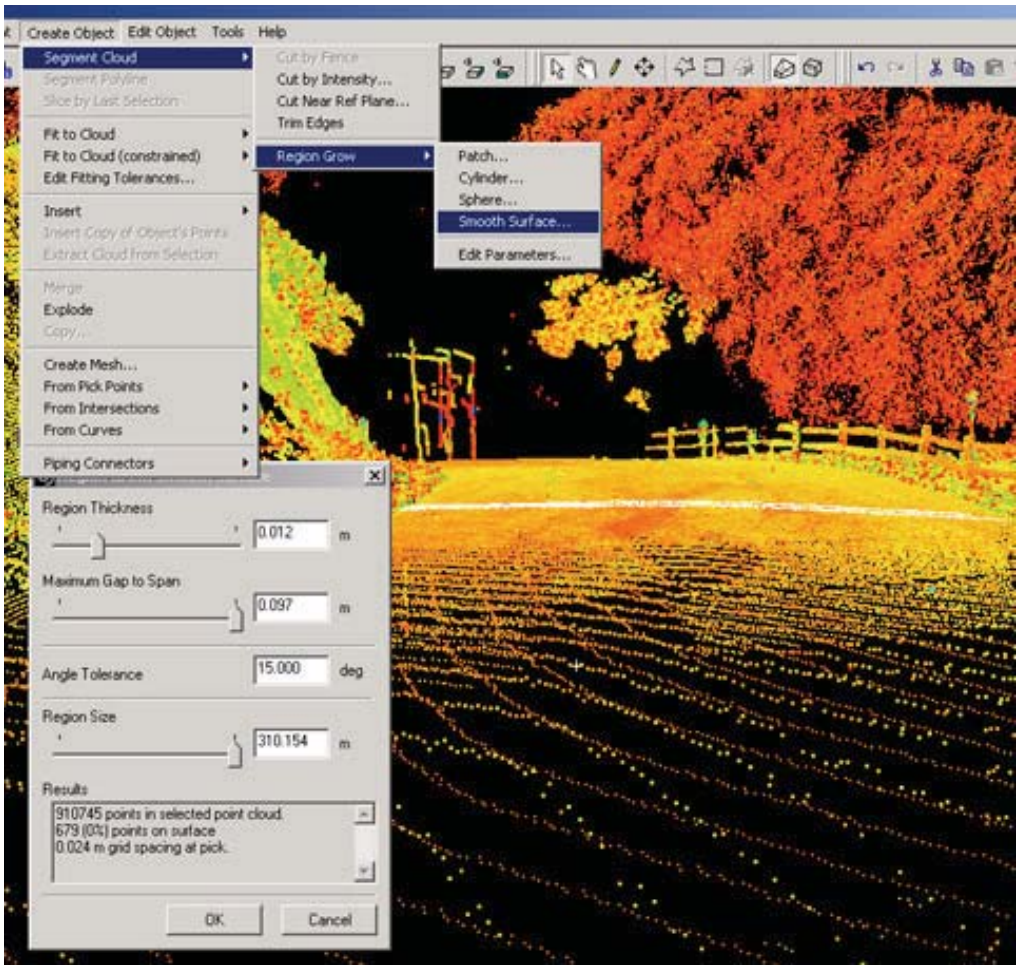
ADVANCED SURVEYING AND MAPPING TECHNOLOGIES

Systems Overview & Applications

Publication No. FHWA-CFL/TD-08-002 **May 2008**



U.S. Department of Transportation
Federal Highway Administration

Federal Lands Highway
Commitment to Excellence

Central Federal Lands Highway Division
12300 West Dakota Avenue
Lakewood, CO 80228

FOREWORD

Within the primary role of transportation engineering and stewardship of highways and bridges over federally owned, and Tribal, lands, the Office of Federal Lands Highway (FLH) of the Federal Highways Administration (FHWA) promotes development and deployment of applied research and technology applicable to solving transportation related issues. The FLH provides technology delivery, innovative solutions, recommended best practices, and related information and knowledge sharing to Federal agencies, Tribal governments, and other offices within the FHWA.

Surveying and mapping in support of environmental planning, design, right of way, construction, and rehabilitation is essential throughout the project delivery process. Due to the nature of typical FLH projects, including remote locations and challenging terrain, these important tasks often represent critical elements to schedule and cost. The FLH has long recognized the importance of high quality, efficient surveying and mapping technology, having pioneered development and deployment of innovative solutions such as electronic data collection and processing, and global navigation satellite system (GNSS) surveying. These experiences, and others, have demonstrated the value in recognizing advances before they become routine or obsolete.

This study was undertaken to assess, in a comprehensive way, the state and applicability of emerging technologies for surveying and mapping work. Particular focus was directed toward ground based laser scanning and airborne positioning and mapping systems. As one of the few professional design and construction agencies with national scope, the FLH provides leadership for sound professional practices. This study of Advanced Surveying and Mapping Technologies is directed at fulfilling that leadership role, while ensuring value for our client's projects.

F. David Zanetell, P.E., Director of Project Delivery
Federal Highway Administration
Central Federal Lands Highway Division

Notice

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COTR: Alan Blair, FHWA-CFLHD. Advisory Panel Members: Roger Surdahl, FHWA-CFLHD. This project was funded under the Federal Lands Highway Technology Deployment Initiatives and Partnership Program (TDIPP).

16. Abstract

This report presents a study, with resulting conclusions, to investigate emerging surveying and mapping technologies, and their applicability to typical assignments of the Office of Federal Lands Highway (FLH) of the Federal Highways Administration (FHWA). This study, conducted in 2002 and 2003 included a review of professional publications, interviews with internal and external consumers and providers of surveying and mapping data, together with field evaluations of certain specific systems. While the study was open to the broad spectrum of emerging technologies at the time, particular focus was directed toward ground based laser scanning and airborne positioning and mapping systems.

Field evaluations of different laser scanner systems, over a previously mapped project, details the advantages and limitations of the instruments and software, and highlights specific conditions most favorable to ground based laser scanning methods. Testing of airborne positioning and attitude determination using global navigation satellite system (GNSS) surveying combined with an inertial guidance system (INS) was shown to provide significant efficiencies for route surveying, particularly where ground control surveys are restricted due to terrain or environmental constraints.

17. Key Words	18. Distribution Statement
LASER SCANNING, LiDAR, MAPPING, POINT CLOUD, SURVEYING	No restriction. This document is available to the public from the sponsoring agency at the website http://www.cflhd.gov.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	Millimeters	mm
ft	feet	0.305	Meters	m
yd	yards	0.914	Meters	m
mi	miles	1.61	Kilometers	km
		AREA		
in^2	square inches	645.2	Square millimeters	mm^2
ft^2	square feet	0.093	Square meters	m^2
yd^2	square yard	0.836	Square meters	m^2
ac	acres	0.405	Hectares	ha
mi^2	square miles	2.59	Square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	Milliliters	mL
gal	gallons	3.785	Liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	Grams	g
lb	pounds	0.454	Kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	Lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	Newtons	N
lbf/in^2	poundforce per square inch	6.89	Kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	Inches	in
m	meters	3.28	Feet	ft
m	meters	1.09	Yards	yd
km	kilometers	0.621	Miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	Acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	Gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	Ounces	oz
kg	kilograms	2.202	Pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	Poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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EXECUTIVE SUMMARY

The subject study was performed in 2002 and 2003 to assess the applicability of advanced surveying and mapping technologies to typical assignments at the Federal Lands Highway Divisions of the Federal Highways Administration. Ground-based laser scanning systems had been identified as an emerging technology that could have applications for surveying and mapping tasks. The study included field demonstration of laser scanning methods on an existing project site in Riverside, California. Visibility limitations from steep terrain and dense brush prevented successful topographic mapping over many of the target locations. Ground-based laser scanning found advantage in those limited applications where visibility and access was not overly complicated, and where the rich detail and accuracy afforded by point cloud data could be exploited. Possible example applications could be documentation of historical resources, or detailed mapping of structures. Airborne Light Detection and Ranging (LiDAR) is similar to ground-based laser scanning, but its downward looking perspective, and the rapid linear coverage, is more applicable to route surveying. Massive amounts of data points are available from a LiDAR mission, providing possibilities for visualizations and virtual topographic mapping through the point cloud data. Airborne LiDAR also finds limitations with visibility through dense vegetation, so heavily forested areas and thick brush are not the best applications. Consideration must also be given to the inability of LiDAR to accurately identify breaklines. Projects with critical features such as curbs or drainage features may require additional work to be correctly depicted. The study included demonstration of airborne positioning technology used in LiDAR systems. The demonstration project used GPS and inertial measurement to supplement ground control for analytical photogrammetry. This combination afforded a 75% reduction in the required ground control for the project.

Since these demonstrations, Central Federal Lands Highway Division has continued to explore new instrumentation and software to enhance surveying and mapping functions. Continuing education and vision will be necessary to prepare for technological changes still emerging.