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National Aeronautics and Space Administration Washington, DC 20546-0001	Approved: 03-21-2007 Expiration Date: 03-21-2012 Superseding NASA-STD-6002B

APPLYING DATA MATRIX IDENTIFICATION SYMBOLS ON AEROSPACE PARTS

MEASUREMENT SYSTEM IDENTIFICATION:
INCH-POUND (METRIC)

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DOCUMENT HISTORY LOG

Status	Document Revision	Approval Date	Description
Baseline		06-01-2001	Baseline Release
Revision	A	09-23-2002	Incorporated metric unit equivalent in parentheses beside all English measurement units. Section 4.1 has a statement added that when measurement terms are expressed, English units are used as the "Primary" expression and Metric units are used as "Secondary" expression, shown in parentheses beside the English units. Section 4.1 has a statement added that data matrix symbols that are applied to the substrate of a part and subsequently covered with paint, foam, and other protective coatings SHALL be applied by the same methods identified in this Standard and its related Handbook, NASA-HDBK-6003A, Application of Data Matrix Identification Symbols to Aerospace Parts Using Direct Part Marking Methods/Techniques. Section 4.2 has modified text that changes the data content order from part number-CAGE-serial number to CAGE-part number-serial number, making this Standard consistent with MIL-STD-130 and other direct part marking standards. It also defines that an asterisk is used to separate those data fields when ASCII format is used and a dash when human readable identification is used. Figure 1 was rearranged to be consistent with the text of Section 4.2.

Status	Document Revision	Approval Date	Description
Revision	B	02-21-2006	Incorporated changes stemming from DoD retrofit part marking development and DPM flight verification tests. Added Appendices A, B, and C. Inputted into new template; made editorial changes.
Revision	C	03-21-2007	1.2: Added: "In all cases when identification is being applied to flight hardware, the responsible Technical Authority shall approve the location of the mark and the method used to apply it." Removed bullet "Electrical, Electronic, and Electro Mechanical (EEE) parts." Added last paragraph: "This standard shall not be used for electrical, electronic, and electromechanical (EEE) parts identification and marking requirements due to concerns relating to electrostatic discharge and component degradation. EEE part marking and identification are addressed in the military standards for the specific part types." Section 2: Deleted "None" under "APPLICABLE DOCUMENTS." Added paragraph 2.1 General; paragraph 2.2 Government Documents and added MIL-STD-130, "Identification Marking of U.S. Military Property," Sections 5.2.4 and 5.2.5 and NASA-STD-(I)-6016, "Standard Materials and Processes Requirements for Spacecraft" as applicable documents; paragraph 2.3 Non-Government Documents and "None"; and added paragraph 2.4 Order of Precedence. 4.1.1: Added "Nanocode™, an" elemental taggant, and replaced "taggant" with "Nanocode ™" in two places.

Status	Document Revision	Approval Date	Description
Revision	C Continued		4.1.2, 1st sentence: Changed to read: "A Part Marking Plan shall be developed in accordance with the requirements of this standard and submitted for NASA approval." Added "h. List parts waived from identification marking due to marking process unavailability." Added "4.1.3.1, Previous Symbol Data Structure for Legacy Items and Ongoing Programs" above text of section 4.1.3, 2-D Symbol Content. Changed second to last sentence changed from "Figure 1 illustrates NASA's data content formats," to "Figure 1 illustrates NASA's legacy data content formats." Deleted last sentence: "In the event an element (product), program, or Agency-wide UID program is implemented, the data content may vary to fit contractual requirements." Figure 1: Changed title from "Preferred 2-D Symbol Data Format" to "Legacy 2-D Symbol Data Format." Changed caption (left-side) from "Data format…area" to "Full data format … area." Changed caption (right-side) from "Data format to be used where marking area is insufficient to place a symbol containing complete data content" to "Unique Identification Data Format." Added "4.1.3.2 Current Symbol Data Structure. Manufacturers that implement the NASA aerospace direct part marking standard shall use marking process requirements in accordance with NASA-STD-6002 and syntax and semantics for the Data Matrix symbol content in compliance with MIL-STD-130, sections 5.2.4 and 5.2.5. Detailed how-to guidance for implementing NASA-STD-6002 requirements is provided in NASA-HDBK-6003. Data Matrix symbols that are subsequently covered with paint, foam, or other protective coatings shall

Status	Document Revision	Approval Date	Description
Revision	C Continued		have the same symbol content requirements as symbols that remain visible throughout their life cycles." Table 3: Changed Optimum Range from "Roughness Average 125 to 2000" to "Roughness Average 8 to 250." 4.2.2.1.1: Added metric unit of measure to "Temperature extremes" bullet. 4.2.2.4, added: "m. Potential damage from selection of an intrusive cleaning process." 4.2.3.2: Deleted the last sentence: "The most commonly used processes to coat surfaces prior to marking are the following:" and replaced it with "The most commonly used processes to coat surfaces prior to marking are listed in the following sub-paragraphs. NOTE: Many of the materials and processes listed may have restrictions on their use in particular applications particularly in space, due to issues such as toxicity, offgassing, whiskering, etc. Consult NASA-STD-(I)-6016 and its referenced documents for guidance on specific materials and follow program-specific requirements." 4.2.3.2.3: Added "(see NASA-STD-(I)-6016, Standard Materials and Processes Requirements for Spacecraft, section 4.1.1.11 Tin" to bullet "Tin and tin alloy plating." 4.2.8, 5th sentence: Changed "of" to "or." 5.1.1: Corrected title of MIL-H-6875 to read: "Heat Treatment of Steel Raw Materials." 5.2: Added key words and deleted related page numbers.

Status	Document Revision	Approval Date	Description
Revision	C Continued		C.1: Changed to read: "For these parts, a chemical taggant known as Nanocode^{TM} . . .." Changed "chemical taggant" to "Nanocode^{TM}" to read: "The Nanocode^{TM} is sprayed . . .." Changed "taggant" to "Nanocode^{TM}" to read: "The x-ray fluorescence scanner and detector used to read the Nanocodes^{TM} are . . .." Changed "X-Ray" to "Nanocode^{TM}" to read: "Nanocode^{TM} using fluorescence works . . .." Changed "Taggants" to "Nanocode^{TM}" to read: "Nanocodes^{TM} are mixtures . . .." Changed "taggant" to "Nanocode^{TM}" to read: "The Nanocode^{TM} is decoded by software . . .." "Taggant" was deleted in the sentence: "Each element represents a different letter . . .." C.2: Changed "XRF" to "Nanocode^{TM}" to read: "Nanocode^{TM} elemental tagging can be used . . .." Changed "XRF taggants" to "Nanocode^{TM}" to read: "Working in conjunction with labels . . . indestructible Nanocodes^{TM} serve . . .." Changed "XRF "secret bar codes" to "Nanocode^{TM} to read: When liability cases occur that possibly involve . . . technologies such as Nanocode^{TM} firmly . . .." Based on revised operating procedures at Headquarters, decimal places rounded to two places were expanded. English to metric measurement corrections were made to the following: 4.1.5, 1st sentence, changed "4 microns" to "0.000157 in" and "(0.0001016 mm)" to "(0.003987 mm)." 4.1.5, 5th sentence, changed "(0.12 mm)" to "0.1905 mm)." Table 1, Marking Process Laser-Shot Peening, changed Typical Data Cell Size from "(0.238 mm)" to "(0.2286 mm)" and P/N, EI and S/N-... from "(5.286 mm)" to "(5.4864 mm)." 4.2.1.7, 1st sentence, added metric measurements for 8 microinches "(0.0002032 mm)" and for 250 microinches "(0.00635 mm)." Table 4, under Minimum Cell Size (Inches), changed line 1 "0.01" to "0.0075" and "(0.19 mm)" to "(0.1905 mm)"; line 2 "0.01" to "0.009" and "(0.23mm)"

	C Continued		to "(0.2286 mm)"; line 3 "0.02" to "0.015" and "(0.38 mm)" to "(0.381 mm)"; line 4 "0.02" to "0.020" and "(0.51 mm)" to "(0.508 mm)"; line 5 "0.03" to "0.025" and "(0.64 mm)" to "(0.635 mm)"; and line 6 "0.03" to "0.030" and "(0.76 mm)" to "(0.762 mm)." Table 5, under Maximum Marking Depth, changed Electro-Chemical Coloring from "(0.06 mm)" to "(0.00508)"; Abrasive Blast from "(0.08 mm)" to "(0.00762)"; and Laser Engraving and Micro-Milling from "(31.75 mm)" to "(3.175 mm)." 4.2.2.3, added "(1093 degrees C.) to "Heat treat to 2000 degrees F. ...)." Table 7, changed heading to read "High Heat (Engines) +2000 ºF (+1093ºC)" and heading "Temperature: -30ºF (-34ºC) to 140ºF (60ºC)." 4.2.3.4, 2nd paragraph, changed to read "Surface texturing shall . . . level above 8 microinches (0.0002032 mm) . . .." 4.2.4.3, last sentence, changed"(20 x 0.022 inches = 0.044 inches square)" to "(20 x 0.022 inches = 0.440 inches square)" and "(20 x 0.559 = 1.118 mm.)" to "(20 x 0.559 = 11.180 mm)." Made editorial and template changes.

FOREWORD

This standard is published by the National Aeronautics and Space Administration (NASA) to provide uniform engineering and technical requirements for processes, procedures, practices, and methods that have been endorsed as standard for NASA programs and projects, including requirements for selection, application, and design criteria of an item.

This standard is approved for use by NASA Headquarters and NASA Centers, including Component Facilities.

This standard establishes uniform requirements for applying Data Matrix identification symbols to parts used on NASA programs/projects using direct part marking (DPM) methods and techniques.

Requests for information, corrections, or additions to this standard should be submitted via "Feedback" in the NASA Technical Standards System at http://standards.nasa.gov.

______________________________________ ____________________

Christopher J. Scolese
NASA Chief Engineer

Approval Date

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Applying Data Matrix Identification Symbols on Aerospace Parts

1. SCOPE

This standard and its related handbook, NASA-HDBK-6003, Application of Data Matrix Identification Symbols to Aerospace Parts Using Direct Part Marking Methods/Techniques (DPM), were developed to provide NASA and its contractors with instructions to safely apply Data Matrix identification symbols to aerospace parts using these new DPM methods and techniques. Both the standard and the handbook were created by representatives from the major automatic identification and data capture (AI/DC) manufacturers, Government, and aerospace user groups under a collaborative agreement with NASA. The standard has been approved by NASA Headquarters for use by all field installations, and is intended to provide a common framework for consistent practices across NASA programs.

Revision B of this standard includes updates stemming from the Department of Defense (DoD)/National Center of Manufacturing Sciences (NCMS) Retrograde Part Marking Program as approved by the Assistant Under Secretary of Defense, and the United States Coast Guard (USCG) Data Matrix Direct Part Marking Flight Verification Program, which was sanctioned by the Flight Safety Critical Aircraft Part Problem Action Team (FSCAP PAT) and the U.S. Congress Aircraft Safety Committee. Revision B planning had called for the incorporation of information resulting from the Materials International Space Station Experiment (MISSE), which exposed the Data Matrix Symbol markings to low-earth orbit (LEO) environments. However, due to delays in the retrieval of the MISSE experiment, information related to marking processes certified for LEO are to be incorporated into a later revision of this document. MISSE program information is included in Appendix A.

1.1 Purpose

This standard establishes uniform requirements for applying Data Matrix identification symbols to parts used on NASA programs/projects using DPM methods and techniques. Overall program/project requirements related to the use of the Data Matrix symbol include symbol criteria, marking method selection, marking surface preparation, marking location, protective coatings, marking environments, and mark-quality verification standards. This document does not specifically address the marking of human-readable characters or temporary part identification markings (bands, labels, or tags). On new programs, human-readable characters can be applied using the same marking methods defined in this standard. Data Matrix symbols can be added to parts used on existing programs if there is adequate area to accommodate the mark and the structural integrity of the part is not compromised.

This standard is intended to provide general requirements for applying Data Matrix identification symbols safely onto products using permanent DPM methods and techniques. The standard addresses symbol structure only as it relates to marking and reading limitations. Technical specifications related to the Data Matrix symbol are found in Automatic Identification Manufacturers (AIM) International, Inc., technical specification titled “International Symbology

Specification – Data Matrix." Technical information on how to apply the markings is addressed in NASA-HDBK-6003.

1.2 Applicability

This standard is applicable to NASA programs/projects using DPM methods and techniques. In all cases when identification is being applied to flight hardware, the responsible Technical Authority shall approve the location of the mark and the method used to apply it.

This standard may be cited in contract, program, and other Agency documents as a technical requirement. Mandatory requirements are indicated by the word "shall." Tailoring of this standard for application to a specific program or project shall be approved by the Technical Authority for that program or project.

This standard explains the use of Data Matrix symbol marking to support updates to Automated Identification Technology (AIT) systems used to provide program managers with real-time hardware status. The standard provides engineering practices for NASA programs and projects. Human-readable markings applied to NASA aircraft maintained under Federal Aviation Administration (FAA) certificate such as Part 121 or Part 135 shall comply with Title 14 of the Code of Federal Regulations. Data Matrix marking shall be used to identify all flight hardware and ground support equipment, including, but not limited to, the following:

- Calibration items
- Critical fasteners
- Fracture-critical parts
- Hazard analysis items
- Items requiring periodic maintenance
- Limited-life items
- Pilferage items
- Repair-limited items
- Restricted-use items
- Safety-critical Items
- Temporary installations
- Other items identified with paint dots or assigned date codes, lot numbers, member numbers, or serial numbers (S/Is) for safety, reliability, maintainability, or quality assurance purposes, including items not currently serialized due to size limitations associated with the applications of human-readable marking.

This standard shall not be used for electrical, electronic, and electromechanical (EEE) parts identification and marking requirements due to concerns relating to electrostatic discharge and component degradation. EEE part marking and identification are addressed in the military standards for the specific part types.

2. APPLICABLE DOCUMENTS

2.1 General

The documents listed in this section contain provisions that constitute requirements of this standard as cited in the text of section 4. The latest issuances of cited documents shall be used unless otherwise approved by the assigned Technical Authority. The applicable documents are accessible via the NASA Technical Standards System at http://standards.nasa.gov, or directly from the Standards Developing Organizations, or other from document distributors.

2.2 Government Documents

MIL-STD-130	Identification Marking of U.S. Military Property – Sections 5.2.4 and 5.2.5
NASA-STD-(I)-6016	Standard Materials and Processes Requirements for Spacecraft – Section 4.2.2.11 Tin

2.3 Non-Government Documents

None.

2.4 Order of Precedence

When this standard is applied as a requirement or imposed by contract on a program or project, the technical requirements of this standard take precedence, in the case of conflict, over the technical requirements cited in applicable documents or referenced guidance documents.

3. ACRONYMS AND DEFINITIONS

3.1 Acronyms

AI/DC	Automatic Identification and Data Capture
AIM	Automatic Identification Manufacturers, 634 Alpha Drive, Pittsburgh, PA 15238-2802. Telephone 412 963-8588
AIT	Automated Identification Technology
AMS	American Meteorological Society
ANSI	The American National Standards Institute. A non-government organization responsible for the coordination of voluntary national (United States) standards. ANSI, 11 West 42nd Street, New York, NY 10036, Telephone: 212.642.4900, Telefax: 212.302.1286
AO	Atomic Oxygen
ASM	American Society for Metals
ASTM	American Society for Testing and Materials

CAGE Code	Commercial and Government Entity Code
CCD	Charged Coupled Device
CEA	Consumer Electronics Association
CMOS	Complementary Metal Oxide Semiconductor
DoD	Department of Defense
DOT	Department of Transportation
DPM	Direct Part Marking
DUNS	Data Universal Numbering System
EAN	International Government Entity
ECC	Error Checking and Correction
ECM	Electrochemical Machining
EDM	Electro Discharge Machining
EEE	Electrical, Electronic, and Electromechanical
EI	Enterprise Identifier
EPA	Environmental Protection Agency
EVA	Extravehicular Activity
FAA	Federal Aviation Administration
FSCAP PAT	Flight Safety Critical Aircraft Part Problem Action Team
GALE	Gas Assisted Laser Etch
HRI	Human-Readable Identification
HVOF	High Velocity Oxygen Fuel
IEC	International Electrotechnical Commission
ISO	International Standards Organization
IVD	Ion Vapor Deposition
Laser	Light Amplification by Stimulated Emission of Radiation
LBM	Laser Beam Machining
LENS	Laser Engineered Net Shaping
LEO	Low-Earth Orbit
LISI	Laser-Induced Surface Improvement
LIVD	Laser-Induced Vapor Deposition
MEK	Methyl Ethyl Ketone
MISSE	Materials International Space Station Experiment
MRI	Machine Readable Identification
NASA	National Aeronautics and Space Administration
NCMS	National Center of Manufacturing Sciences
NSCM	NATO Supply Code for Manufacturers
P/N	Part Number
PECs	Passive Experiment Containers
RMS	Roughness Measurement Scale
S/N	Serial Number
UCC	Uniform Code Council
UID	Unique Identification
USCG	United States Coast Guard

UV	Ultra Violet
VOCs	Volatile Organic Compounds
WD	Working Draft
XRF	X-Ray Fluorescence

3.2 Definitions

2-D: Two dimensional.

Age Life Item: Any item designated as having a limited useful life regardless of whether it is limited operating life, limited shelf life, operating life sensitive, or combinations of these. This includes fluids, elastromers, and polymers, where appropriate.

ASCII: American Standard Code for Information Interchange. The code is used in the transmission of data. The code consists of eight data-bits used to code each alphanumeric character or other symbol.

Bad-Read: A decodes operation that results in the output of inaccurate data.

Bar Code: A patterned series of vertical bars of varying widths used by a computerized scanner for inventory, pricing, etc.

Binary Value: A mark on the substrate surface indicating the binary of one or the absence of a mark or a smooth surface surrounding a cell center point indicating the binary value of zero.

Bit (Binary Digit): The basic unit of information in a binary numbering system. The binary system uses 1s and 0s.

Centerline of a Row or Column: The line positioned parallel to, and spaced equally between, the boundary lines of the row or column.

Character (Data Character): A letter, digit, or other member of the ASCII character set.

Character Set: Character available for encoding in a particular automated identification technology.

CO_2: Type of laser using carbon dioxide gas as the lasing medium.

Contrast: The grayscale difference between two areas of color.

Data Element: The smallest named item of information that can convey data, analogous to a field in a data record or a word in a sentence.

Data Element Separator: The special character used to separate data elements in a data format.

Data Matrix Symbol: A 2-D array of square or round cells arranged in contiguous rows and columns. In certain Error Checking and Correction (ECC) 200 symbols, data regions can be separated by alignment patterns. The data region is surrounded by a finder pattern (AIM – Data Matrix).

Density (Matrix Density): The number of rows and columns in a scanned matrix symbol.

Depth of Etch: The distance from the surface of the substrate to the bottom of the recess created by an etching process.

Direct Part Marking: Markings applied directly to a part's surface using intrusive or non-intrusive identification techniques.

Dot: A localized region with a reflectance which differs from that of the surrounding surface.

Edge: A dramatic change in pixel brightness values between regions. It is the point(s) that has the greatest amount of contrast difference (change in intensity values) between pixels.

EEE Parts: EEE (electrical, electronic, and electromechanical) parts such as capacitors, connectors, diodes, inductors, microcircuits, relays, resistors, switches, transistors, and transformers.

Electrolyte: The solution formed by water and a selected salt(s) and used as the conductor between an object and electrode in an electro-chemical marking process. Selected electrolytes also have the ability to "color" the mark due to the chemical reaction that takes place between the metal and the electrolyte.

Enterprise Identifier (EI): A code used to define each entity location that has its own unique, separate, and distinct operation. An enterprise may be an entity such as a manufacturer, supplier, depot, program management office, or third party. An enterprise identifier is a code uniquely assigned to an enterprise by a registered issuing agency. An issuing agency is an organization responsible for assigning a non-repeatable identifier to an enterprise, i.e., Dun & Bradstreet's Data Universal Numbering System (DUNS) number, Uniform Code Council (UCC)/ International Government Entity (EAN) Company Prefix, Allied Committee 135 Commercial and Government Entity (CAGE) number, or coded representation of the North American Telecommunication Industry Manufacturers, Suppliers, and Related Service Companies (American National Standards Institute (ANSI) T1.220) Number.

Error Checking and Correction (ECC): Mathematical algorithms used to identify symbol damage and reconstruct the original information, based upon the remaining data in a damaged or poorly printed code. Reed Solomon and convolution are two such techniques.

Field of View: The maximum area that can be viewed through the camera lens or viewed on the monitor.

Finder Pattern of a Data Matrix Code Symbol: A perimeter to the data region. Two adjacent sides contain dots in every cell which are used primarily to define physical size, orientation, and symbol distortion. The two opposite sides are composed of cells containing dots in alternate cells (AIM – Data Matrix).

Good-Mark: A mark that can be decoded (read) successfully 10 out of 10 tries with the reader in focus and positioned at a 90-degree angle to the target (± 20 degrees) under any light condition.

Good-Read: A successful decoding attempt that results in the output of accurate data.

Grayscale: The assignment of a digital value to a degree of light intensity. The shades of gray are used by the computer to reconstruct an image. A common scale is 256 shades of gray, with 0 being black and 255 being white.

Hardness: A measure of the resistance of a material to surface indentation or abrasion. Hardness may be considered as a function of the stress needed to produce some specified type of surface deformation. There is no absolute scale for hardness; therefore, to express hardness quantitatively, each type of test has its own scale of arbitrarily defined hardness. Indentation hardness can be measured by Brinell, Rockwell, Vickers, Knoop, and Scleroscope hardness tests.

Human-Readable Identification: The letters, digits, or other characters incorporated into linear bar code or 2-D symbols and readable by humans.

Intensity: The average of the sum total of grayscale value.

Intrusive Marking: A mark made by any device designed to alter a material surface to form a human- or machine-readable symbol. These marking devices include, but are not limited to, devices that abrade, burn, corrode, cut, deform, dissolve, etch, melt, oxidize, or vaporize a material surface.

kHz: Kilohertz (1000 cycles of oscillation per second).

License Tag Number: The information contained with the symbol character set to uniquely identify the component. As a minimum, the information contains the manufacturer's CAGE code followed by an asterisk (ASCII separator) and trace code (lot, member, or serial number).

Manufacturer: Producer or fabricator of a component or the supplier in a transaction if the supplier is the warrantor of the component.

Mark: Refers to a Data Matrix symbol that has been applied to a material surface using a permanent marking method.

Matrix: A set of numbers, terms, or items arranged in rows and columns.

Matrix Density: The number of rows and columns in a matrix.

Nd:YAG: Type of laser using a Neodymium Yttrium Aluminum Garnet crystal as the lasing medium.

Nd:YVO_4: Type of Laser using a Neodymium-Doped Yttrium Vanadate crystal as the lasing medium.

No-Read: An unsuccessful decoding attempt that results in no data output.

Non-Intrusive Marking: A method of forming markings by adding material to a surface. Non-intrusive marking methods include ink jet, laser bonding, liquid metal jet, silk screen, stencil, and thin film deposition.

Part Identification Data: Markings used to relate parts to their design, manufacturing, test, and operational histories.

Permanent Marking: Intrusive or non-intrusive markings designed to remain legible beyond the normal service life of an item.

Photo-Stencil: A silk-screen type fabric coated with a photo-resist compound that can be fixed by Ultra Violet (UV) radiation and easily washed from the fabric where unexposed. The patterns opened in the fabric are the images to be marked (stenciled, etched, or colored) on the substrate.

Pilferage Items: Items, such as tools, that are easily stolen.

Pixels: Picture elements. In a camera array, pixels are photoelectric elements capable of converting light into an electrical charge.

Quiet Zone: Areas of high reflectance (spaces) surrounding the machine-readable symbol. Quiet zone requirements may be found in application and symbology specifications. Sometimes called “Clear Area” or “Margin.”

Reader: A general term used to describe an optical-based or sensor-based symbol capture device. “Optical-based reader” is another name for a Changed Coupled Device (CCD) or Complementary Metal Oxide Semiconductor (CMOS) camera. Sensor-based readers, used to capture symbol images hidden from view are similar to optical readers, except that the CCD or CMOS is replaced with a sensor that can discern the symbol from its background. Sensor-based readers utilize magnetic, capacitance, thermal, x-ray, ultrasound, micro-impulse radar, or other similar sensing mechanisms to detect and capture hidden images.

Resolution: The measure of how small a feature the camera can distinguish in its field of view. The number of pixels within the CCD array determines camera resolution. The more pixels used to capture the image, the higher the resolution or quality of the image. Since the number of pixels is fixed, the smaller the field of view, the higher the image resolution. For example, a 1-inch (25.4 mm) field of view photographed by a 640 x 480 pixels camera with a resolution of .0015-inch (0.04 mm) per pixel; a ½-inch (12.7 mm) field of view has a resolution of .00078-inch (0.02 mm) per pixel.

Structure: The order of data elements in a message.

Substrate: The material (paper, plastic, metal, etc.) upon which a symbol is marked.

Supplier: The trading partner in a transaction that provides the component (e.g., manufacturer, distributor, reseller, etc).

Symbology: A machine-readable pattern composed of a quiet zone, finder pattern, symbol characters (which include special functions and error detection and/or correction characters) needed for a particular symbology.

Temporary Identification: Markings designed to be removed or separated from items before they reach the end of their life cycle.

Thermal Stencil: Similar to the photo-stencil. In this case, the fabric is coated with a compound, which can be opened by a thermal printer to form the desired images.

Traceability: For purposes of this document, "traceability" is defined as the ability to relate historical documentation to parts using part identification numbers.

4. REQUIREMENTS

4.1 General Requirements

4.1.1 2-D Symbol

The ECC 200 Data Matrix symbology shall be the direct part marking method for machine readable identification (MRI) used on all flight hardware and associated ground support equipment. The Data Matrix symbol is preferred for direct-part identification marking on NASA programs/projects unless otherwise directed by contract. The symbols are applied in addition, and in proximity to, the human-readable identification (HRI) markings currently used. On new programs/projects, the HRI and MRI symbol-markings are applied simultaneously and by the same method whenever practical. The Data Matrix symbol is a 2-D matrix symbology approved by the AIM for direct-part marking. There are two symbol types: ECC 000 – 140 with several available levels of convolutional ECC, and ECC 200, which uses Reed-Solomon error correction. For new NASA applications, ECC 200 shall be required. ECC 000 – 140 should only be used in closed applications where a single party controls both the production and reading of the symbols, and is responsible for overall system performance. The characteristics of Data Matrix symbols are defined within AIM's Uniform Symbology Specification for Data Matrix document.

When process parameters of symbol size, height, or depth are expressed in linear terms on drawings and other documents, metric equivalents are included. English units serve as the "Primary" expression and metric units are "Secondary" expression, shown in parentheses beside the English units.

Data Matrix symbols that are applied to the substrate of a part and subsequently covered with paint, foam, and other protective coatings use the same methods identified in this standard and its related handbook, NASA-HDBK-6003. The imaging of subsurface identification symbols relies primarily on the ability of a detection device to sense and image the hidden symbol. Intrusive methods of marking normally benefit detection devices that sense differences in surface regularity. Non-intrusive or additive methods normally benefit detection devices that sense substances exhibiting a different characteristic from that of the substrate. Examples of sensor-based readers that image intrusive and non-intrusive markings through coatings are shown in Appendix B.

Nanocode™, an elemental taggant technology, used in combination with an x-ray fluorescence (XRF) detection system, is a useful method for identifying and authenticating a part. X-ray fluorescence may be used for detecting elements from the periodic table in known concentrations to represent subsurface identification characters. It is recommended that the resulting spectral data output be expressed in the approved Data Matrix format for automatic decoding by software in the detection system. The selected elements may be applied as Nanocode™ constituents of the Data Matrix symbol or as a standalone identifier.

The spectral data output of standalone selected Nanocode™ elements, the constituent substances in a symbol mark, the substrate itself, or any combination of these constitutes valid part identification only if these conventions are formally accepted and the acceptance is documented. Examples of XRF readers are shown in Appendix C.

4.1.2 Part Marking Plan

A Part Marking Plan shall be developed in accordance with the requirements of this standard and submitted for NASA approval.

The Part Marking Plan, as a minimum, shall address the following:

a. Objectives of the Part Marking Plan

b. Equipment and software requirements for on-site and in the field

c. Part identification methods for each type of part/material

d. Part marking processes and procedures

e. Automation of related records, reports, forms, and databases

f. Adherence to requirements for a unique identification (UID) program for parts

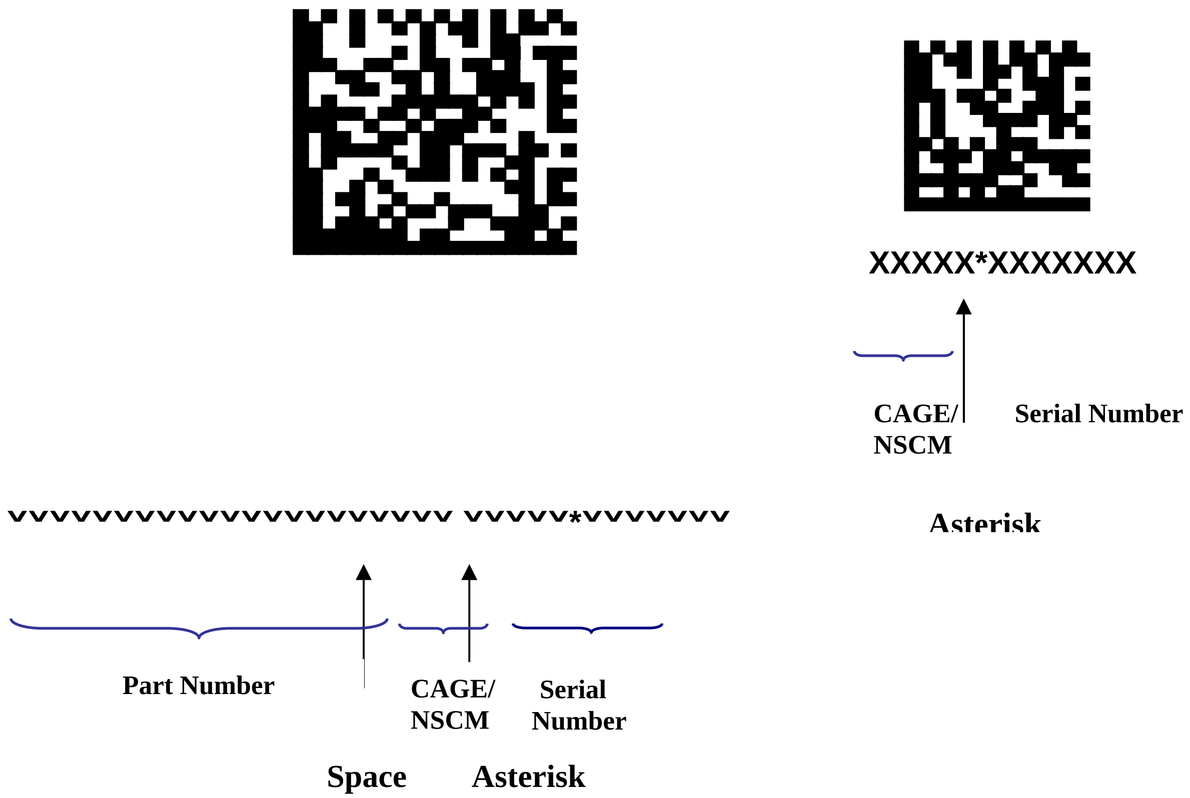
g. Compatibility of identification and marking approach across configuration, logistics, and other data systems at the element (product) and program levels

h. List parts waived from identification marking due to marking process unavailability

4.1.3 2-D Symbol Content

4.1.3.1 Previous Symbol Data Structure for Legacy Items and Ongoing Programs

The full-part identification data to be encoded into the 2-D symbol consists of a part number (P/N) that is typically 15 to 21 characters, followed by a space to separate it from the unique part identifier; the Enterprise Identifier (EI); an asterisk ASCII separator for machine-readable identification symbols; and a unique lot, member, or serial number. In instances where space is prohibitive, the PN can be excluded from the data content and an abbreviated traceability number used. The traceability number or unique part identification number consists of the users, EI, and unique seven-digit lot number or serial number, separated by an asterisk in the machine-readable symbol. These data-encoding and marking options provide program managers with the ability to use a more damage-resistant symbol (larger data cells) over a greater range of part sizes. Data Matrix symbols that are subsequently covered with paint, foam, or other protective coatings shall have the same symbol content requirements as symbols that remain visible throughout their life cycles. Figure 1 illustrates NASA's legacy data content formats.



Full data format to be used in areas providing sufficient marking area.

Unique Identification Data Format

Figure 1—Legacy 2-D Symbol Data Format

4.1.3.2 Current Symbol Data Structure

Manufacturers that implement the NASA aerospace direct part marking standard shall use marking process requirements in accordance with NASA- STD- 6002 and syntax and semantics for the Data Matrix symbol content in compliance with MIL-STD-130, sections 5.2.4 and 5.2.5. Detailed how-to guidance for implementing NASA-STD-6002 requirements is provided in NASA-HDBK-6003. Data Matrix symbols that are subsequently covered with paint, foam, or other protective coatings shall have the same symbol content requirements as symbols that remain visible throughout their life cycles.

4.1.4 2-D Symbol Shape

The Data Matrix symbol can be created in square and rectangular formats, the square format being preferred (see figure 2). However, for some linear-shaped parts such as pipes, lines, narrow part edges, etc., it may be more desirable to use a rectangular-shaped symbol. The intent is to use a symbol shape providing the largest-size data cells.

Preferred symbol shape for narrow marking areas

Square Symbol

Rectangular Symbol

Figure 2—Data Matrix Symbol Shapes

4.1.5 2-D Symbol Size

Data Matrix symbols can be produced in sizes ranging between 0.000157 inch (0.003987 mm) square to 2 feet (609.6 mm) square, with the limiting factors being the capability and fidelity of the marker. Symbol size is not an issue using fixed-station readers that are configured to accept different-sized lenses or with hand-held readers configured with variable or multiple lenses. Hand-held readers configured with fixed lenses, to reduce cost and complexity, are generally limited to reading symbols within specific size ranges, i.e., read small symbols, large symbols, or some compromise zone. In general, fixed-lens hand-held readers are used in applications where symbol size is fixed, and variable or multiple-lens readers are used in applications requiring the use of different sized 2-D symbols and/or bar codes. Regardless of lens type, hand-held readers are generally limited to reading symbols containing individual data cells that measure 0.0075 inch (0.1905 mm) across or larger. An overall symbol size of less than 1-1/2 inches (38.1 mm) on the outside dimension of the longest side shall be required. For purposes of this standard, symbol sizes are divided into three categories: micro symbols containing data cells that are < 0.008 inch (0.2032 mm), typical symbols with data cells ranging between 0.008 inch and 0.034 inch (0.2032 mm to 0.8636 mm), and macro-size symbols with data cells ≥0.035 inch (0.889 mm).

4.1.6 Part Identification Conflicts

Any conflicts between HRI and the Data Matrix symbol markings shall be resolved, including update of documentation and databases.

4.2 Detailed Requirements

4.2.1 Marking Method Requirements

Detailed instructions related to the application of DPM methods are contained in NASA-HDBK-6003.

a. The specific marking method shall be selected to ensure product integrity.

b. Material degradation and hazard analysis studies shall be required for safety-critical part applications.

Selection of Data Matrix symbol marking method is influenced by a number of different factors. These factors need to be analyzed closely to ensure that the appropriate marking method is selected. The factors to be considered are summarized as follows.

4.2.1.1 Part Function

Part function is an important consideration in selecting the marking method.

a. Non-intrusive marking methods are recommended for safety-critical parts, i.e., parts which could fail, resulting in hazardous conditions.

b. Intrusive markings in safety-critical areas shall be documented and approved.

4.2.1.2 Part Geometry

Flat surfaces are preferred over curved surfaces for marking. A rectangular symbol shall be applied to cylindrical parts, either concave or convex. The rectangle is sized to fit either within the reflective band of light that emanates from the spine of the curve or on 5 percent of the circumference. This band of light typically occupies 16 percent of the diameter of the curve under normal room light and can increase in size under bright light conditions. Figure 3 illustrates the proper method for marking curved surfaces.

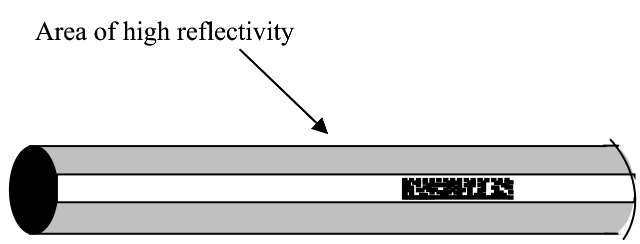


Figure 3—Proper Placement of Data Matrix Symbols on a Curved Surface

Highly polished metal surfaces that are Roughness Measurement Scale (RMS) 0 to 8 should be textured prior to marking to reduce glare (see section 4.2.3, Marking Surface Preparation). The textured area should extend one symbol width beyond the borders of the marking, as illustrated in figure 4.

Textured Patch Applied to Highly Reflective Surface to Reduce Glare

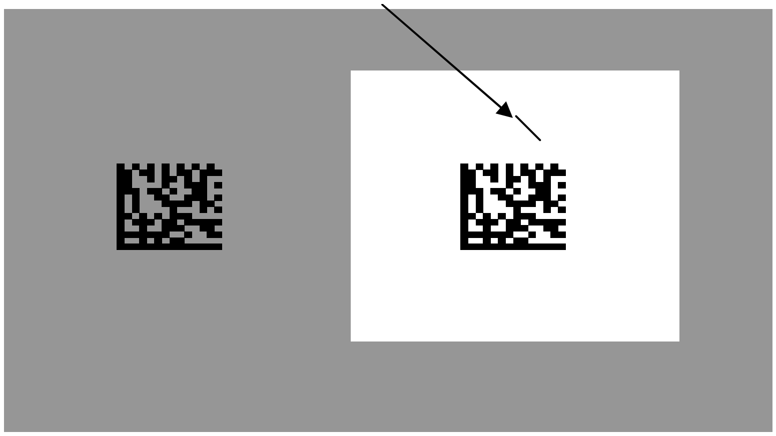


Figure 4—Textured Patch Applied to Reduce Glare

4.2.1.3 Part Size

Part size does not become a factor in 2-D symbol marking until the available marking area is reduced to below 1/4 inch (6.35 mm) square. Below this level, the number of marking options is reduced significantly. Table 1 provides typical symbol sizes by marking process.

Table 1—Symbol Sizes by Marking Process

Symbol Size Categories	Marking Process	Typical Data Cell Size (Ascending Order)	Data Format		
			P/N, EI and S/N - Typically 29 Characters (24x24 Matrix)	EI and S/N - Typically 13 Characters (18x18 Matrix)	S/N Only - Typically 7 Characters (12x12 Matrix)
Micro - <0.008 inch (0.2032 mm) data cells	Laser Marking – Short Wave Length (Excimer)	0.0002 inch (0.00508 mm)	0.004 inch (0.1016 mm)	0.003 inch (0.0762 mm)	0.002 inch (0.0508 mm)
Typical - 0.08 inch (2.032 mm) to 0.034 inch (0.8636 mm) data cells	Laser-Shot Peening	0.009 inch (0.2286 mm)	0.216 inch (5.4864 mm)	0.162 inch (4.1148 mm)	0.108 inch (2.7432 mm)
	Stencil (Photo-Process)	0.010 inch (0.254 mm)	0.240 inch (6.096 mm)	0.180 inch (4.572 mm)	0.120 inch (3.048 mm)
	Laser Bonding	0.010 inch (0.254 mm)	0.240 inch (6.096 mm)	0.180 inch (4.572 mm)	0.120 inch (3.048 mm)
	Laser Marking	0.010 inch (0.254 mm)	0.240 inch (6.096 mm)	0.180 inch (4.572 mm)	0.120 inch (3.048 mm)
	Stencil (Mechanical Cut)	*0.020 inch (0.508 mm)	0.480 inch (12.192 mm)	0.360 inch (9.144 mm)	0.240 inch (6.096 mm)
	Adhesive Dispensing	0.020 inch (0.508 mm)	0.480 inch (12.192 mm)	0.360 inch (9.144 mm)	0.240 inch (6.096 mm)
	Dot Peen*	*0.022 inch (0.5588 mm)	0.528 inch (13.4112 mm)	0.396 inch (10.0584 mm)	0.264 inch (6.7056 mm)
	LISI	0.024 inch (0.6096 mm)	0.576 inch (14.6304 mm)	0.432 inch (10.9728 mm)	0.288 inch (7.3152 mm)
	Stencil (Laser Cut)	*0.024 inch (0.6096 mm)	0.580 inch (14.732 mm)	0.440 inch (11.176 mm)	0.288 inch (7.3152 mm)
	Abrasive Blast	0.025 inch (0.635 mm)	0.600 inch (15.240 mm)	0.450 inch (11.430 mm)	0.300 inch (7.620 mm)
	Ink Jet	0.030 inch (0.762 mm)	0.720 inch (18.288 mm)	0.540 inch (13.716 mm)	0.360 inch (9.144 mm)
Macro – ≥ 0.035 inch (0.889 mm)	Engraving/Milling	*0.040 inch (1.016 mm)	0.960 inch (24.384 mm)	0.720 inch (18.288 mm)	0.480 inch (12.192 mm)
	Fabric Weaving	0.040 inch (1.016 mm)	0.960 inch (24.384 mm)	0.720 inch (18.288 mm)	0.480 inch (12.192 mm)
	LENS	0.040 inch (1.016 mm)	0.960 inch (24.384 mm)	0.720 inch (18.288 mm)	0.480 inch (12.192 mm)
	Fabric Embroidery	0.045 inch (1.143 mm)	1.080 inch (27.432 mm)	0.810 inch (20.574 mm)	0.540 inch (13.716.mm)
	Cast, Mold & Forge	0.060 inch (1.524 mm)	1.440 inch (36.576 mm)	1.080 inch (27.432 mm)	0.720 inch (18.288 mm)

* Includes spacing between data cells

4.2.1.4 Material Type

The primary factor in the selection of an appropriate marking method is the material being marked. Table 2 provides a listing of common marking methods by material type.

4.2.1.5 Material Hardness

Material hardness does not have an effect on the application of non-intrusive or non-contact marking methods. Hardness does have a direct effect on tool wear when engraving, milling, or stamp impression (dot or laser-shot peen) marking methods are used. Tool wear and tool damage shall be monitored closely on metals or metal alloys hardened above 35 Rockwell C.

Table 2—Marking Method Selection

	METALLICS								NON-METALLICS								
MATERIAL TO BE MARKED / MARKING PROCESS	Aluminum	Anodized	Beryllium	Carbon Steel	Copper	Brass	Magnesium	Titanium	Ceramics	Glass	Cloth	Painted	Plastics	Rubber	Teflon	Wood	Others
Abrasive Blast	•	•		•	•	•	•	•	•			•	•		•		•
Adhesive Dispensing	•	•	•	•	•	•	•	•	•	•	1	•	•	•		•	•
Cast, Forge or Mold	•	•	•	•	•	•	•	•	•				•	•			
Dot Peen	•			1	•	1 •						1	•				
Electro-Chem Coloring	•	•	•	•	•	•	•	•									
Electro-Chem Etching	•	•	•	•	•	•	•	•									
Embroidery											•						
Engraving/Milling	•	•		•	•	•						1	•			•	
Laser Bonding	•		•	•		•	•	•	•	•							
Laser - Short Wave Lengths	•	1	•	•	•		•	•	•	•		1	•	•	•	•	•
Laser - Visible Wave Lengths	1	1		•	1	•						1	•				
Laser – Long Wave Lengths		1								•		1				•	
Laser Shot Peening	•	1	2	2	•	2	2	•				1	•				
LENS	•	1	•	•	•	•	•	•									
LISI	•	2		•	•		2	2									
Ink Jet	•	•	•	•	•	•	•	•	•	•	1	•	•	•			•
Silk Screen	•	•	•	•	•	•	•	•	•	•		•	•	•		•	•
Stencil	•	•	•	•	•	•	•	•	•	•		•	•	•		•	•
Thin Film Deposition	•	•	•	•	•	•	•	•	•	•			•	•			•

• = Acceptable marking process for noted material
1 = Contact Engineering before proceeding
2 = Marking method still under development

Given the number of variables to be considered, selection of a marking device based on speed is accomplished on a case-by-case basis.

4.2.1.6 Surface Color

Dark-colored markings are generally applied to light surfaces and light markings applied to dark surfaces. The minimum contrast difference between the symbol and its substrate that can be reliably read is 20 percent as shown on a standard grayscale comparator (see figure 5). The minimum acceptable contrast level is 40 percent at point of marking to allow for degradation over time in the use environment (see section 4.2.1.8, Optimum Data Matrix Marking Range). In situations where surface colors change (camouflage patterns), care must be taken to apply marks in an area of uniform color.

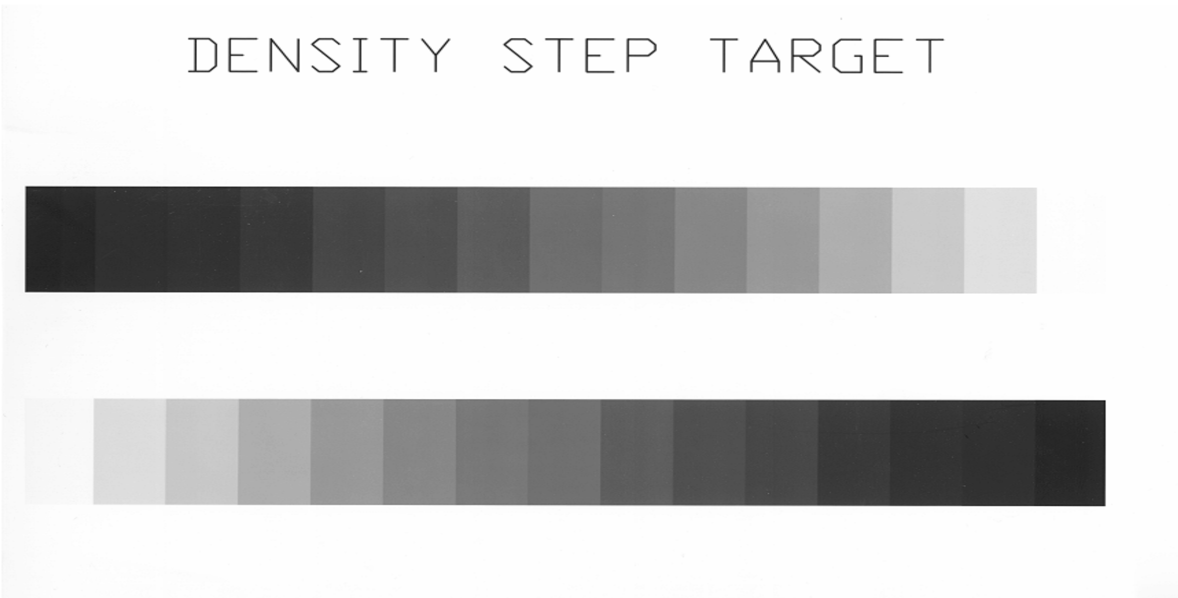


Figure 5—Typical Grayscale Comparator

4.2.1.7 Surface Roughness/Finish

Symbol marking should be limited to surface roughness levels averaging between 8 microinches (0.0002032 mm) and 250 microinches (0.00635 mm) (millionth of an inch [0.0000254 mm]) unless the marking method utilized is specifically designed for use on extreme rough surfaces (reference table 3). Surfaces that fall outside of acceptable surface roughness levels can also be resurfaced as defined in section 4.2.1.8, Optimum Data Matrix Marking Range, or marked with labels, tags, or identification plates (figures 6 and 7).

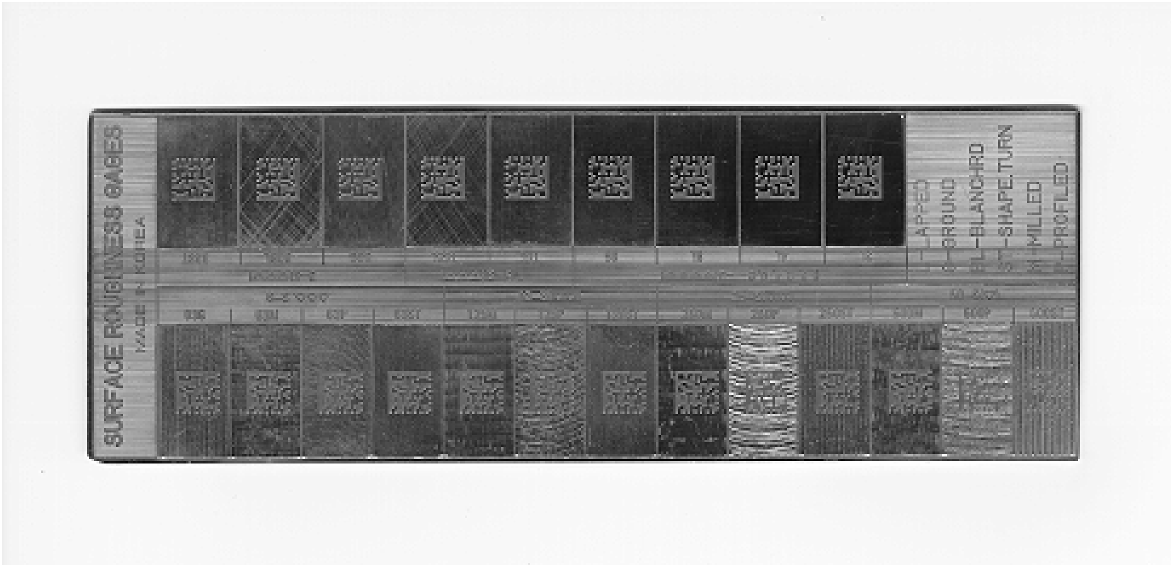


Figure 6—Typical Microfinish Comparator

Table 3—Ranges of Average Surface Roughness by Processing Method

Processing Category	Processing Method	Roughness Average (R_a) µin.											
		1	2	4	8	16	32	63	125	250	500	1000	2000
Machining	Lapped												
	Ground												
	Blanchard												
	Shape Turned												
	Milled												
	Profiled												
Nonabrasive Finishing	ECM												
	EDM												
	LBM												
Blasting	Grit Blasting												
	Sand Blasting												
	Shot Peening												
Cast Surfaces	Die												
	Investment												
	Shell Mold												
	Centrifugal												
	Permanent Mold												
	Non-ferrous Sand												
	Ferrous Green Sand												

Optimum Range

4.2.1.8 Optimum Data Matrix Marking Range

Cast surfaces present a unique symbol decoding challenge, because the surface irregularities (pits) create shadows that can be misinterpreted by the decoding software such as dark data cells.

a. Consequently, individual data cells in the symbol must be larger than the surface irregularities so that the decoding software can differentiate between the two features.

b. The data cells contained in the symbol must be increased in size in direct proportion to the average surface roughness level to ensure successful decoding. Some particular marking methods are capable of producing large raised or indented cell sizes that are much larger than surface irregularities on extremely rough-surfaced parts. Figure 7 and table 4 provide a formula and minimum cell size restrictions developed to aid in determining minimum symbol sizes to be used on cast surfaces.

c. Otherwise, the area to be marked must be treated to provide a smoother substrate for the mark. Figure 8 shows the relationship between cell size and cast surface roughness.

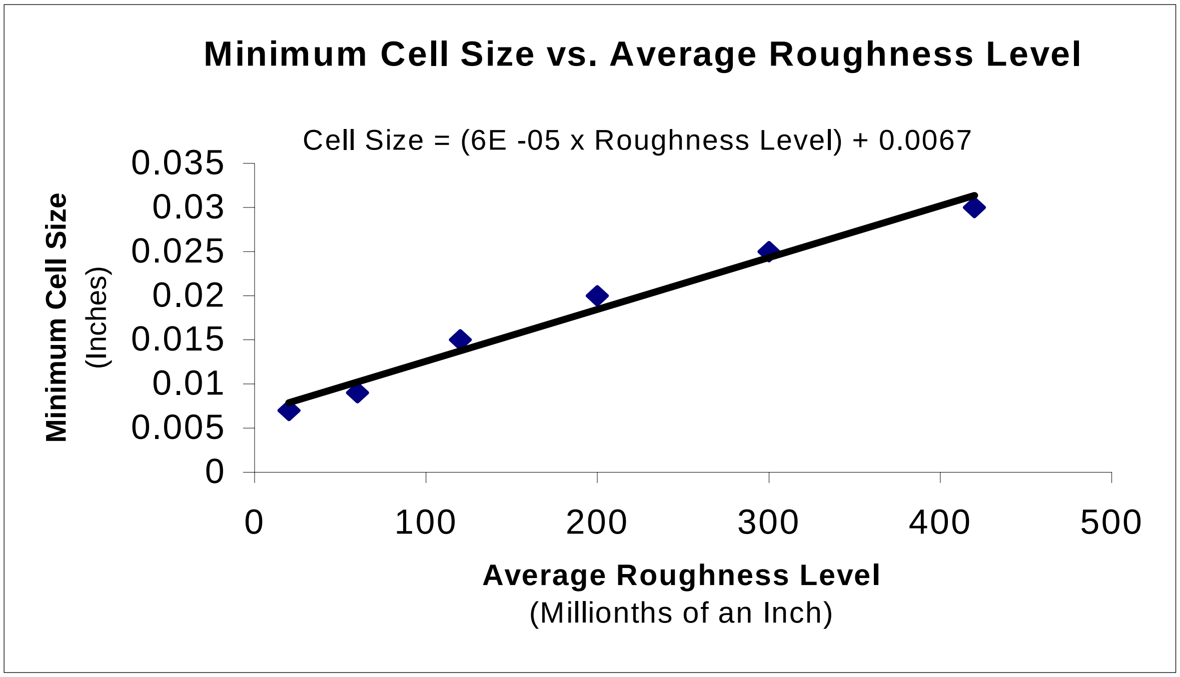


Figure 7—Minimum Cell Size vs. Average Roughness Level

Table 4—Minimum Readable Cell Size by Roughness Level

Average Roughness Level (millionths of an inch [0.0000254 mm])	Minimum Cell Size (Inches)
20 (0.000508 mm)	0.0075 (0.1905 mm)
60 (0.001524 mm)	0.009 (0.2286 mm)
120 (0.003048 mm)	0.015 (0.381 mm)
200 (0.005080 mm)	0.020 (0.508 mm)
300 (0.007620 mm)	0.025 (0.635 mm)
420 (0.010668 mm)	0.030 (0.762 mm)

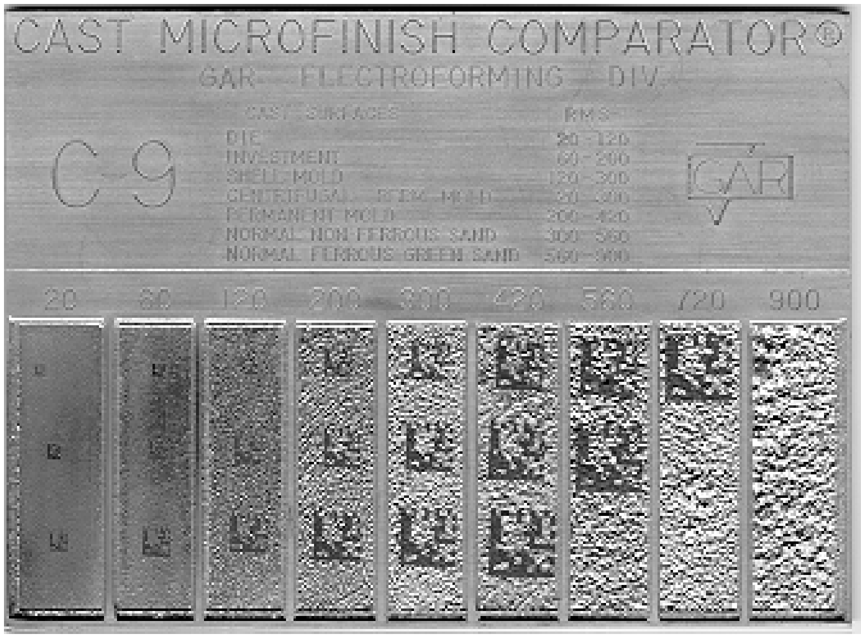


Figure 8—Comparator Showing Relationship Between Cell Size and Cast Surface Roughness

4.2.1.9 Surface Thickness

Surface thickness must be considered in applying intrusive markings to prevent deformation or excessive weakening of the part.

a. The degree of thickness for intrusive marking shall be directly related to the heat, depth, or force applied.

b. In most applications, the marking depth shall not exceed 1/10 the thickness of the part (10x mark/etch). Table 5 defines the maximum practical marking depth that can be obtained using intrusive marking methods. Part thickness is generally not a consideration in applying non-intrusive markings.

Table 5—Minimum Recommended Substrate Thickness by Marking Method

Marking Method	Maximum Marking Depth	Minimum Part Thickness
Laser Bonding	Surface Mark	0.001 inch (0.0254mm)
Electro-Chemical Coloring	0.0002 inch (0.00508 mm)	0.002 inch (0.0508 mm)
Abrasive Blast	0.0003 inch (0.00762 mm)	0.003 inch (0.0762mm)
Acid Etch – Stencil	0.0005 inch (0.0127 mm)	0.005 inch (0.127 mm)
Chemical Coloring – Stencil	0.001 inch (0.0254 mm)	0.010 inch (0.254 mm)
Laser Annealing	0.001 inch (0.0254 mm)	0.010 inch (0.254 mm)
Laser Shot-Peening	0.002 inch (0.0508 mm)	0.020 inch (0.508 mm)
Electro-Chemical Etch	0.002 inch (0.0508 mm)	0.020 inch (0.508 mm)
Laser Etch	0.003 inch (0.0762 mm)	0.030 inch (0.762 mm)
LISI	0.004 inch (0.1016 mm)	0.040 inch (1.016 mm)
Dot Peen	0.004 inch (0.1016 mm)	0.040 inch (1.016 mm)
Laser Engraving	0.125 inch (3.175 mm)	1.250 inch (31.75 mm)
Micro-Milling	0.125 inch (3.175 mm)	1.250 inch (31.75 mm)

4.2.1.10 Operating Environment/Age Life

Users should verify that the marking method selected produces a mark that can survive in its intended environment and retain a minimum grade of "C" while in use as defined in International Standards Organization (ISO)-15415.

In order to establish durability and longevity, specifications to control processes and marking material quality to pass durability tests shall be developed for the environment intended. Tests typically used for this purpose are identified in table 6.

Table 6—Marking Method Test Specifications

Test	Specification Number	Specification Title
Abrasion Resistance	American Society for Testing and Materials (ASTM) D-4060-01	Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser
Adhesion	ASTM D3359 02	Standard Test Methods for Measuring Adhesion by Tape Test
Atmospheric Acid Pollution Resistance	ASTM D1308-02E1 (with addition of sulfuric acid testing)	Standard Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes
Bending Test	ASTM D522-93a (2001)	Standard Test Methods for Mandrel Bend Test of Attached Organic Coatings
	ASTM D3794 00	Standard Guide for Testing Coil Coatings
Boiling Water	ASTM D870 02	Standard Practice for Testing Water Resistance of Coatings Using Water Immersion
Chemical Resistance	Not Applicable	1 hour immersion in appropriate chemical
Corrosion Resistance	ASTM B117 03	Standard Practice for Operating Salt Spray (Fog) Apparatus
Hardness	ASTM D3363 00	Standard Test Method for Film Hardness by Pencil Test
Impact	ASTM D2794-93 (2004)	Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)
Mar Resistance	ASTM D673-93ae1 (withdrawn)	Standard Test Method for Mar Resistance of Plastics
Thermal	ASTM D2485-91 (2000)	Standard Test Methods for Evaluating Coatings For High Temperature Service
Transparency	ASTM D1003-03 (not active)	Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics Transparency
Ultraviolet Exposure	ASTM G154	Standard Practice for Fluorescent for UV Exposure of Nonmetallic Materials
Water Resistance	ASTM D870 02	Standard Practice for Testing Water Resistance of Coatings Using Water Immersion

Table 6—Marking Method Test Specifications (continued)

Test	Specification Number	Specification Title
Water Resistance	ASTM D2247 02	Standard Practice for Testing Water Resistance of Coatings in 100% Relative Humidity
Water Vapor	ASTM E96 00e1	Standard Test Methods for Water Vapor Transmission of Materials
Weathering	ASTM G155-00ae1	Standard Practice for Operating Xenon-Arc Light Apparatus for Exposure of Non-metallic Materials
NOTE: ASTM specifications can be acquired from the American Society For Testing and Materials, West Conshohocken, PA.		

4.2.1.11 Production Rates (Marking Time)

Process times for marking a symbol on the surface of a part are affected by a variety of factors including, but not limited to, the following:

- Symbol size
- Symbol density
- Marking device
- Mask or mold production (if required)
- Data input
- Part movement and positioning
- Part holding/clamping (if required)
- Operator proficiency

4.2.2 Marking Environments

Government testing has been conducted to assess the effects of environments on the survivability of the part-marking processes described in this standard. During these tests, part markings were subjected to all of the typical environments encountered during both ground and flight operations (including LEO) as well as during part servicing, repair, and overhaul. These environments are summarized in tables 7 and 8, and this information is provided to aid users during the marking selection process.

4.2.2.1 Operational Environments

4.2.2.1.1 Ground and Sub-Orbital Flight

- Abrasion per ASTM D4060-95 or G132-96
- Chemical Exposure
  - Cleaners such as Methyl Ethyl Keytone (MEK)
  - Deicers
  - Dye penetrant
  - Fuel such as JP4/5
  - Grease
  - Hydraulic Fluid
  - Liberating Oils
  - Paint Stripper
- Foreign object damage (minor)
- Salt fog spray per ASTM B117-95
- Temperature extremes: -30°F (-34° C) to +140°F (+60° C), engines components up to + 2000°F (1093° C)
- Ultra-violet light per ASTM G23-96 or G26-95

4.2.2.1.2 Low-Earth Orbit

- Exposure to atomic oxygen (AO)
- Irradiation with high-energy particles
- Exposure to solar ultra-violet (UV) radiation
- Impact by space debris or meteoroid particles
- Temperature extremes

4.2.2.2 Service and Repair Environments

- Acid etch per TT-C-490
- Alkaline cleaning per TT-C-490
- Detergent wash per TT-C-490
- Emulsion cleaning per TT-C-490
- Mechanical/abrasion cleaning per TT-C-490
- Solvent wash per TT-C-490
- Steam cleaning per TT-C-490
- Ultra-sonic cleaning per ASTM G131-96
- Vapor degreasing per TT-C-490
- Penetrant inspection per MIL-STD-6866 (media MIL-I-25135E)

4.2.2.3 Overhaul Environments

- Abrasion blast per MIL-STD-1504 (Plastic Media - MIL-P-85891)
- Abrasion blast per MIL-STD-1504 (Glass Media - MIL-G-9954)
- Abrasion blast per MIL-STD-1504 (Garnet Media - MIL-A-21380)
- Abrasion blast per MIL-STD-1504 (Aluminum Oxide Media)
- Abrasion blast per MIL-STD-1504 (Grit Media - MIL-G-5634)
- Temper etch per MIL-STD-867
- Acid dip (Phosphoric or Sulfuric Acid)
- Flame spray strip per MIL-STD-869
- Heat treat to 2000 degrees F. (1093 degrees C.) per MIL-STD-6875
- High Velocity Oxygen Fuel (HVOF) strip per MIL-STD-871
- Ion Vapor Deposition (IVD) strip per MIL-STD-871
- Paint strip per MIL-STD-871 (T.O. 4S-1-182)
- Plate strip per MIL-STD-871
- Shot peen per AMS-S-13165, intensity 0.006A to 0.010A, Shot S-230 to S-330

Table 7—Ground, Sub-Orbital, and Low-Earth Orbit Environments

Marking Process	Part Environments															
	Ground and Sub-Orbital Operations (DoD Supplied)											Low-Earth Orbit Operations (NASA Supplied -MISSE)				
	Abrasion	Chemicals - Deicer	Chemicals- Fuels	Chemicals - Grease	Chemicals - Hydraulic Fluid	Chemicals - Lubricating Oil	Foreign Object Damage (minor)	High Heat (Engines) +2000°F (+1093°C)	Temperature: -30°F (-34°C) to 140°F (60°C)	Ultra-Violet	Salt Spray	Atomic oxygen	High Energy Particles	Ultra-Violet (UV)	Debris & Meteoroid Impact	Temperature Extremes
Cast Forge and Mold	X	X	X	X	X	X	X		X	X	X	X		X		X
Dot Peen	X	X	X	X	X	X		R	X	X	X	X		X		X
Electro-Chem. Coloring		X	X	X	X	X			X	X						
Electro-Chem. Etch With Color Added*																
Ink Jet*				X												
Laser Bonding		X	X	X	X	X	X		X	X	X					
LENS		X		X												
Laser–Coloring				X												
Laser–Engraving (Direct)	X	X	X	X	X	X	X	R	X	X	X	X		X		X
Laser–Engraving (Coat & Remove) *				X												
Laser–Etch (Coat and Mark)				X												

Table 7—Ground, Sub-Orbital, and Low-Earth Orbit Environments (continued)

Marking Process	Part Environments															
	Ground and Sub-Orbital Operations (DoD Supplied)											Low-Earth Orbit Operations (NASA Supplied -MISSE)				
	Abrasion	Chemicals - Deicer	Chemicals - Fuels	Chemicals - Grease	Chemicals - Hydraulic Fluid	Chemicals - Lubricating Oil	Foreign Object Damage (minor)	High Heat (Engines) +2000°F (+1093°C)	Temperature: -30°F (-34°C) to 140°F (60°C)	Ultra-Violet	Salt Spray	Atomic oxygen	High Energy Particles	Ultra-Violet (UV)	Debris & Meteoroid Impact	Temperature Extremes
Laser–Etch (Direct)	X	X	X	X	X	X	X		X	X	X					
Laser–Etch (Gas Assisted)				X												
Laser – Induced Surface Improvement		X	X	X	X	X	X		X	X	X					
Laser–Induced Vapor Deposition																
Laser-Shot Peen		X	X	X	X	X			X	X	X					
Mechanical Engraving	X	X	X	X	X	X	X	X	X	X	X	X		X		X
Silk Screen*								U								
Stencil-Chemical Coloring								U								
Stencil–Ink*								U								
Stencil–Thermal Spray		X	X	X	X	X			X							
Paper Labels	U	U	U	U	U	U		U	X							U
Polymeric Labels				X	X	X		U	X	X	X					U
Metallic Tags, Bands and Nameplates								U	X	X	X					

Legend: X = Marking remains readable, R = Marking can be restored to readable status,
U = Marking rendered unusable, Blank = Testing Not Completed
*Clear coat required, ** Incorporated for comparison purposes

Table 8—Service, Repair, and Overhaul Environment

Marking Process	Part Environments																						
	Service & Repair (DoD Supplied)									Overhaul (DoD Supplier)													
	Acid Etch	Alkaline Cleaning	Detergent Wash	Emulsion Cleaning	Mechanical/Abrasion	Solvent Wash	Steam Cleaning	Ultra-Sonic Cleaning	Vapor Degreasing	Penetrate Inspection	Abrasive Blast - Plastic	Abrasive Blast - Glass	Abrasive Blast - Garnet	Abrasive Blast – Al Ox	Abrasive Blast - Grit	Acid Dip	Flame Spray	HVOF Strip	IVD Strip	Paint Strip	Plating Strip	Shot Peen	Heat Treat
Cast Forge and Mold (Metal)	**X**	**X**	**X**	**X**		**X**	**X**	**X**	**X**	**X**							**X**			**X**	**X**		**X**
Dot Peen		**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**													
Electro-Chem. Coloring																							
Electro-Chem. Etch																							
Engraving	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**R**	**X**	**X**	**X**	**X**	**X**	**R**
Ink Jet*																							
Laser Bonding																							
LENS		**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**													
Laser–Coloring																							
Laser–Engraving (Direct)	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**R**	**X**	**X**	**X**	**X**	**X**	**R**
Laser–Engraving (Coat & Remove)																							
Laser–Etch (Coat and Mark)																							
Laser–Etch (Direct)		**X**	**X**			**X**	**X**		**X**	**X**													
Laser–Etch (Gas Assisted)																							
Laser - Induced Surface Improvement		**X**	**X**	**X**		**X**	**X**	**X**	**X**	**X**													
Laser–Induced Vapor Deposition																							
Laser-Shot Peen																							
Silk Screen*	**U**				**U**					**U**	**U**	**U**	**U**	**U**	**U**	**U**	**U**	**U**	**U**				**U**
Stencil–Ink*	**U**				**U**					**U**	**U**	**U**	**U**	**U**	**U**	**U**	**U**	**U**	**U**				**U**
Stencil–Thermal Spray																							
Paper Labels**	**U**	**U**	**U**	**U**	**U**	**U**	**U**	**U**	**U**	**U**	**U**	**U**	**U**	**U**	**U**	**U**	**U**	**U**	**U**	**U**	**U**	**U**	**U**
Polymeric Labels**			**X**		**U**	**X**	**X**	**X**			**U**	**U**	**U**	**U**	**U**	**U**	**U**	**U**		**U**	**U**		**U**
Metallic Tags, Bands, and Nameplates**			**X**	**X**		**X**	**X**	**X**		**X**								**U**					

Legend: X = Marking remains readable, R = Marking can be restored to readable status,
U = Marking rendered unusable, Blank =Testing not completed
* = Clear coat required, ** = Show for comparison purposes

4.2.2.4 Cleaning

Cleaning processes used for removing soils and contamination are varied, and their effectiveness depends on the requirements of the specific application. In selecting a metal cleaning process, many factors must be considered, including the following:

a. The nature of the soil to be removed
b. The substrate to be cleaned (i.e., ferrous, non-ferrous, etc.)
c. The importance of the condition of the surface to the end use of the part
d. The degree of cleanliness required
e. The existing capabilities of the available facilities
f. The environmental impact of the cleaning process
g. Cost considerations
h. The total surface area to be cleaned
i. Effects of previous processes
j. Rust inhibition requirements
k. Material handling factors
l. Surface requirements of subsequent operations, such as phosphate conversion coating, painting, or plating
m. Potential damage from selection of an intrusive cleaning process

4.2.3 Marking Surface Preparation

Prior to marking, the requirement for surface preparation shall be determined by an analysis that addresses the following points:

a. Surface finishes that cause excessive amounts of shadowing and/or glare
b. Surfaces that do not provide the necessary contrast for decoding
c. Safety-critical parts that cannot be marked using intrusive marking methods
d. Materials that are not conducive to marking with the user's preferred marking method

The most common methods utilized to prepare surfaces for marking are additives and coatings.

4.2.3.1 Additives

Specialized additives can be mixed with metal alloys and thermoplastic formulations to enhance and optimize marking contrast. These additives, mixed into the substrate material, increase the ability of the substrate material to absorb specific wavelengths of laser light, but do not generally affect overall material performance.

4.2.3.2 Coatings

Coatings are used to modify a part surface to improve its characteristics and/or provide corrosion protection. Coatings can be utilized to aid part marking by the following:

- Smoothing rough surfaces to reduce the effects of shadowing
- Providing contrast for part surfaces that are within gray-scale mid-range
- Dulling highly polished surfaces to reduce glare
- Providing a surface that can be removed with intrusive markings to expose a substrate of contrasting color
- Providing a surface that can be discolored or textured with an intrusive marking method to produce the required level of contrast
- Serving as a media for marking using a stencil as a mask

The most commonly used processes to coat surfaces prior to marking are listed in the following sub-paragraphs. NOTE: Many of the materials and processes listed may have restrictions on their use in particular applications particularly in space, due to issues such as toxicity, offgassing, whiskering, etc. Consult NASA-STD-(I)-6016 and its referenced documents for guidance on specific materials and follow program-specific requirements.

4.2.3.2.1 Dip, Barrier, and Conversion Coating

"Dip, barrier, and chemical conversion coating" is a term that encompasses a family of processes used to prevent corrosion. These coating processes include

- Anodizing
- Babbitting
- Ceramic coatings and linings
- Chromate conversion coatings
- Elastomeric coatings for automotive plastics
- Electrodeposited coatings
- Hot-dip coatings
- Hot-dip galvanized coatings
- Painting
- Phosphate coatings
- Porcelain enameling
- Rust-preventative compounds

4.2.3.2.2 LISI

Light Amplification by Stimulated Emission of Radiation (Laser)-Induced Surface Improvement (LISI) is a laser process used to instill stainless properties to carbon steel. The process differs from laser bonding in that the coating material is mixed with the substrate to form an improved alloy with high corrosion-resistant properties. The process can also be used to improve the wear characteristics of aluminum surfaces. LISI-treated surfaces can be discolored or removed to form a Data Matrix symbol.

4.2.3.2.3 Plating and Electroplating

Plating and electroplating processes are divided into two categories: electro deposition and non-electrolytic deposition processes. The processes associated with these categories are listed as follows:

Electro deposition:

- Cadmium plating
- Copper and copper alloy plating
- Chromium alloy plating
- Decorative chromium plating
- Electroforming
- Gold plating
- Indium plating
- Industrial (hard) chromium plating
- Iron plating
- Lead plating
- Multi-layer alloy plating
- Nickel plating
- Platinum-group plating
- Pulsed-current plating
- Selective (brush) plating
- Silver plating
- Tin and tin alloy plating (see NASA-STD-(I)-6016, Standard Materials and Processes Requirements for Spacecraft, section 4.2.2.11 Tin)
- Zinc plating

Non-electrolytic:

- Electro-less alloy plating
- Electro-less copper plating
- Electro-less gold plating
- Electro-less nickel plating
- Mechanical plating

4.2.3.2.4 Vacuum-Controlled Atmosphere Coating and Surface Modification Processes

Vacuum-controlled atmosphere coatings are general terms that encompass thermal spray, chemical vapor deposition, physical deposition, diffusion, and pulsed-laser deposition processes. This family of processes is used to modify surfaces by depositing material to part surfaces that are to be marked. Vacuum-controlled atmosphere coatings and surface modification processes can be used as media application methods for use with stencil marking.

4.2.3.3 Machining

Machining is normally performed to bring the average surface roughness level to less than 250 microinches (0.00635 mm). Reader tests have proven that surfaces rougher than 250 microinches (0.00635 mm) produce shadows that adversely affect hand-held reader performance in using symbols in the micro to standard sizes (1/6-inch (4.2333-mm) to 1/2-inch (12.7-mm) square). The most commonly used machining methods for surface smoothing are described below.

4.2.3.3.1 Blanchard (Ground)

Grinding removes material from a part with a grinding wheel or abrasive belt.

4.2.3.3.2 Lapping

Lapping is performed by rubbing two surfaces together, with or without abrasives, to obtain extreme dimensional accuracy or superior surface finish.

4.2.3.3.3 Milling

Milling is performed using a rotary tool, with one or more teeth, that removes material as the part moves past the rotating cutter.

4.2.3.3.4 Profiling

Profiling is a milling process that duplicates external or internal profiles in two dimensions. A tracing probe follows a 2-D template, and through electronic or air-actuated mechanisms, controls the cutting spindles in two mutually perpendicular directions. The spindles – usually more than one – are set manually in the third dimension.

4.2.3.3.5 Shape Turning

Shape turning is designed to remove material by forcing a single-point cutting tool against the surface of a rotating work piece. The tool may or may not be moved toward or along the axis of rotation while it removes material.

4.2.3.4 Texturing

Texturing is commonly used to roughen surfaces prior to marking to reduce the amount of glare emanating from the surface. Glare has been shown to have an adverse effect on the ability of 2-D readers to image and decode symbols of any size.

Surface texturing shall bring the surface finish to an average roughness level above

8 microinches (0.0002032 mm) as defined by ASME B46.1 and MIL-STD-10A. Texturing of part surfaces prior to marking is normally performed by the following.

4.2.3.4.1 Abrasive Blast

A process for finishing of an abrasive directed at high velocity against a part. Abrasive blasting methods include grit blasting, sandblasting, and shot blasting.

4.2.3.4.2 Electrochemical Machining (ECM)

ECM is the process in which a controlled metal is removed by anodic dissolution. Direct current passes through a flowing film of conductive solution that separates the part from the electrode/toll. The part is the anode, and the tool is the cathode.

4.2.3.4.3 Electro Discharge Machining (EDM)

EDM is metal removal by rapid-spark discharge between polarity electrodes, one on the part, and the other on the tool, separated by a gap distance of 0.0005 to 0.035 inches (0.0127 to 0.889 mm). The gap is filled with dielectric fluid and metal particles, which are melted, partly vaporized, and expelled from the gap.

4.2.3.4.4 Laser Beam Machining (LBM)

Lasers are used to texture surfaces by melting the surface to refine its appearance. Lasers' effectiveness depends on the requirements of the application. In selecting a metal-cleaning process, many factors must be considered, including the following:

a. The nature of the soil to be removed
b. The substrate to be cleaned (i.e., ferrous, non-ferrous, etc.)
c. The importance of the surface's condition to the part's end use
d. The degree of cleanliness required
e. The existing capabilities of the available facilities
f. The environmental impact of the cleaning process
g. Cost considerations
h. The total surface area to be cleaned
i. Effects of previous processes
j. Rust-inhibition requirements
k. Material-handling factors
l. Surface requirements of subsequent operations, such as phosphate conversion coating, painting, or plating

4.2.3.5 Cleaning Processes used with DPM

The most commonly used cleaning processes used in conjunction with DPM are listed in the following sections.

4.2.3.5.1 Acid Cleaning

Acid cleaners more diluted than acid-pickling solutions are effective for removing light, blushing rust, such as the rust on ferrous metal parts in high humidity or short-time exposure to rain. Acid deoxidizing solutions, specifically designed for use on aluminum, shall be used before electroplating or chemical coating. Various organic acid-based solutions, such as citric acid, are used to remove rust from stainless steels, including the 400 series and the precipitation-hardening steels.

4.2.3.5.2 Alkaline Cleaning

Alkaline cleaning is a commonly used method for removing many soils from the surface of metals. Soils removed by alkaline cleaning include oils, grease, waxes, metallic fines, and dirt. Alkaline cleaners are applied by either spray or immersion facilities and are usually followed by a warm-water rinse. A properly cleaned metal surface optimizes the performance of a coating that is subsequently applied by conversion coating, electroplating, painting, or other operations. The main chemical methods of soil removal by alkaline cleaner are saponification, displacement, emulsification and dispersion, and metal-oxide dissolution.

4.2.3.5.3 Compliance Wipe

Compliance wipe solvents shall be used to remove contaminants from parts before they undergo manufacturing operations that require clean surfaces, such as bonding, sealing, painting, welding, plating, specialized surface treatment, etc. Traditional wipe solvents include the following:

- Methyl ethyl ketone
- Methyl isobutyl ketone
- Trichloroethene (trichloroethylene)
- Tetrachloromethane (perchloroethylene)
- 1,1,1,-trichloroethane (methyl chloride)
- Acetone
- Toluene
- Dichloromethane (methylene chloroform)
- Tetrachloromethane (carbon tetrachloride)
- Benzene
- Xylene
- Ethylene glycol ethers
- Diethylene glycol ethers
- 1,1,2-troichloro-1,2,2-trifluoroethane chlorinated fluorocarbon (CFC-113)
- Combination of these materials

The U.S. Environmental Protection Agency (EPA) has classified these materials as being either hazardous air pollutants or ozone-depleting substances that have been or are to be banned from use in the future. Wipe-solvent materials shall meet EPA requirements for the emission of volatile organic compounds (VOCs), the reduction or elimination of hazardous air pollutants, and the elimination of ozone-layer depleting substances. Alternative materials are identified in MIL-C-38736.

Other solvents are obtainable under the following commercial brand names: Exxon Corporation's Isopar C, Isopar E, Isopar G, Isopar, H, Isopar, K, Isopar L, Isopar M, Isopar V, and Axarel 9100 (isoparaffins) and 3M™ company's PF-5050, PF-5052, PF-5060, PF-5070, and PF-5080 (perflurocarbons).

4.2.3.5.4 Emulsion Cleaning

Emulsion cleaning is an industrial cleaning process that uses an organic solvent as the main active agent. The solvent is usually a hydrocarbon of distilled petroleum dispersed in water. The emulsion, which alone is potentially volatile, is suspended in a nonvolatile aqueous vehicle. Most emulsion cleaners include emulsifying agents, and some are aided by surfactants. Emulsion cleaners are generally used when alkaline or acid cleaners are not applicable.

4.2.3.5.5 Mechanical Cleaning Systems

Mechanical cleaning systems are available for most industrial production applications to remove contaminants and prepare the work surface for finishing or coating. Typical uses include the following:

- Removing rust, scale, dry solids, mold, sand, ceramic shell coatings, or dried paint
- Roughening surfaces in preparation for bonding, painting, enameling, or other coating substances.
- Removing large burrs or weld spatter
- Developing a uniform surface finish, even when slightly dissimilar surfaces are present
- Removing flash from rubber or plastic molding operations
- Carving or decorative etching of glass, porcelain, wood, or natural stone such as granite or marble

The types of parts that can be mechanically cleaned are as follows:

- Ferrous and nonferrous castings
- Forgings or stampings
- Steel plate, strip, or structural shapes
- Welds and other fabrications of ferrous and nonferrous materials
- Aluminum, magnesium, zinc permanent-mold, or die-cast items
- Thermoplastic or thermoset plastics
- Steel bar stock and wire rod

- Precision molded rubber parts
- High-alloy dies and molds for rubber, plastic, glass, or metal parts
- Miscellaneous exotic parts

Mechanical cleaning systems use various types of abrasive materials that are energized or propelled against the work surface or part using one of the following methods:

- Airless centrifugal blast blade- or vane-type wheels
- Compressed air, direct-pressure dry blast nozzle systems
- Compressed-air, indirect-suction (induction) wet- or dry-blast nozzle systems
- Aggressive vibratory systems
- Media tumbling systems
- Part-on-part tumbling system

4.2.3.5.6 Molten Salt Bath Cleaning

Molten salt baths are anhydrous, fused chemical baths used at elevated temperatures for industrial cleaning applications, including the following:

- Removal of organic polymers and coatings
- Dissolution of sand, ceramic, and glassy materials
- Stripping of plasma carbide coatings

In addition, molten salt baths may be used to pre-treat cast-iron surfaces before brazing, bonding, or marking. Molten salt baths for cleaning applications are chemically active or reactive fluids with unique process capabilities. The chemistry involved during cleaning applications ranges from simple dissolution of contaminants to more complex reactions involving the thermo-chemical oxidation of organics and the electrolysis of molten salts.

4.2.3.5.7 Pickling and Descaling

Pickling is the most common process used to remove scale from steel surfaces. The term “pickling” refers to the chemical removal of scale by immersion in an aqueous acid solution. The process originated in the late 1700s when sheets of steel were de-scaled by immersion into vats of vinegar. Variations are possible in the type, strength, and temperature of the acid solutions used, depending on the time constraints (batch versus continuous operations) and the thickness, composition, and physical nature (cracks) of the scale. Pickling is applicable to many types of forgings and castings and for merchant bar, blooms, billets, sheet, strip, wire, and tubing.

4.2.3.5.8 Solvent Cold-Cleaning and Vapor-Degreasing

Solvent cleaning is a surface-preparation process that is especially adept at removing organic compounds such as grease or oil from the surface of a metal. Most organic compounds are easily made soluble by an organic solvent and removed from the parts. In some cases, solvent cleaning before other surface preparations can extend the life of cleaning operations and reduce costs. Solvent cleaning is often used to prepare parts for marking. Before marking, solvent cleaning is usually followed by an alkaline wash or another similar process that provides a hydrophilic surface. Solvent cleaning can also be used to remove water from parts marked with plating, laser-bonding, or similar marking processes.

Solvent cleaning can be accomplished in room-temperature baths or through vapor-degreasing techniques. Room temperature solvent-cleaning is referred to as "cold cleaning." Vapor degreasing is the process for cleaning parts by condensing vapors of a solvent on parts. Parts may also be degreased by immersion in the hot solvent, as well as by exposure to the solvent vapor. Drying is accomplished by evaporating the solvent from the parts, as they are withdrawn from the hot-solvent vapor. In cold cleaning, the parts are dried at room temperature or by external heat, centrifuging, air blowing, or an absorptive medium. The use of many industrial solvents is being severely restricted because of health, safety, and environmental concerns.

4.2.3.5.9 Ultrasonic Cleaning

Ultrasonic cleaning (Ref. STM G-131) involves the use of high-frequency sound waves above 18 kHz to remove a variety of contaminates from parts immersed in aqueous media. The contaminants can be dirt, oil, grease, buffing/polishing compounds, or mold-release agents. Materials that can be cleaned include metals, glass, ceramics, etc. Ultrasonic agitation can be used with a variety of cleaning agents. Ultrasonic cleaning removes tough contaminants without damaging the substrate. It provides excellent penetration and cleaning in the smallest crevices and between tightly spaced parts in a cleaning tank.

4.2.3.5.10 Classification and Selection of Cleaning Processes

Classification and selection of cleaning processes are defined in American Society for Metals (ASM) Surface Engineering Handbook, Vol. 5.

4.2.3.5.11 Cleanliness Verification

Appropriate levels of cleanliness can be verified using the test methods defined in ASTM G-120 and ASTM G-144.

4.2.4 Marking Methods

DPM is generally suggested in applications where

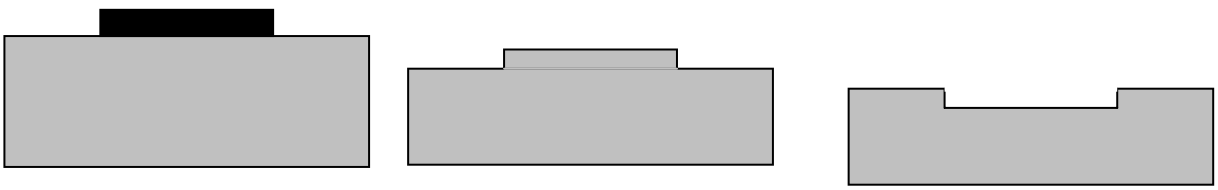
- Traceability is required after the product is separated from its temporary identification.
- The part is too small to be marked with bar-code labels or tags.
- The part is subjected to environmental conditions that preclude the use of add-on identification.
- Identification is required beyond the expected life of the part to preclude further use.

DPM can be divided into two categories: non-intrusive and intrusive. Figures 9 and 10 provide cross-sectional views of direct part markings described in this section.

4.2.4.1 Non-Intrusive Marking Methods

Non-intrusive markings, also known as additive markings, are produced as part of the manufacturing process or by adding a layer of media to the surface using methods that have no adverse effect on material properties. These methods include the following:

- Adhesive dispensing
- Cast, forge, or mold
- Ink jet
- Stencil markings
- Thin-film deposition
- Laser engineered not shaping (LENS)
- Silk screen marking



Additive Markings – Adhesive dispensing, Ink Jet, Laser Bonding, LENS, Silk Screen, Stencil, and Thin Film Deposition

Raised Markings – Cast, Forge, or Mold

Recessed Markings – Cast, Forge, or Mold

Figure 9—Data Matrix Symbol Non-Intrusive Marking Cross Sections

4.2.4.2 Intrusive Marking Methods

Intrusive markings that alter a part's surface (abrade, cut, burn, vaporize, etc.) are considered to be controlled defects and if not applied properly can degrade material properties beyond a point of acceptability. Consequently, some intrusive markings, especially direct laser, are generally not used in safety-critical applications without appropriate metallurgical testing. Typical intrusive marking methods include the following:

- Abrasive blast
- Direct-laser marking
- Dot peen (stamp impression)
- Electro-chemical etching (electrolytic surface coloring or metal removal processes)
- Engraving/milling
- Fabric embroidery
- Laser-shot peening

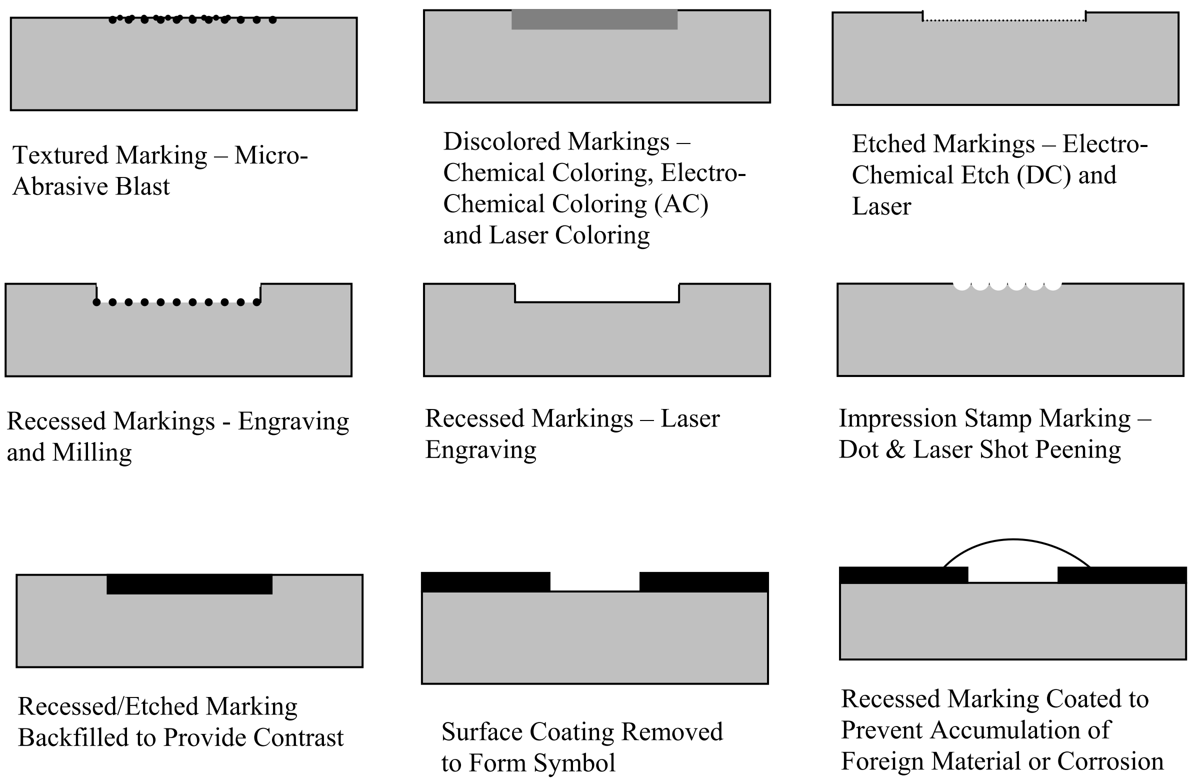


Figure 10—Data Matrix Symbol Intrusive Marking Cross Sections

4.2.4.3 Data Matrix Symbol Size

Symbol size is directly related to the amount of data encoded in the symbol and the fidelity of the marker. Symbol size is determined by establishing the number of rows and columns needed to contain the encoded part information (see table 9) and multiplying that number by the data cell size to be produced by the marker. For instance, a symbol containing 20 characters of ASCII data can be stored in a symbol with 20 rows and columns. If the operator elects to use a dot peen marker that produces a data-cell size of 0.022 inch (0.5588 mm), the overall symbol size is 0.044 inch square (1.1176 mm), (20 x 0.022 inches = 0.440 inches square), (20 × 0.559 = 11.180 mm).

Table 9—Symbol Size Calculation Chart

Data Matrix Parameters ECC 200					Information Capacity			Data Matrix cell sizes 0.003 , 0.008, 0.010, 0.20, .040 Data Matrix symbol size is returned below (Cell and symbol sizes are in inches)				
Rows x Columns	Data Regions	Data Bytes	Error Bytes	Percent ECC	Numeric Only (0-9)	Alphanumeric (0-9, A-Z, space) or (0-9, a-z, space)	8-bit ASCII (0-255)	0.003	0.008	0.010	0.020	0.040
10 x 10	1	3	5	62.5	6	3	1	0.03 x 0.03	0.08 x 0.08	0.10 x 0.10	0.20 x 0.20	0.40 x 0.40
12 x 12	1	5	7	58.3	10	6	3	0.04 x 0.04	0.10 x 0.10	0.12 x 0.12	0.24 x 0.24	0.48 x 0.48
14 x 14	1	8	10	55.6	16	10	6	0.04 x 0.04	0.11 x 0.11	0.14 x 0.14	0.28 x 0.28	0.56 x 0.56
16 x 16	1	12	12	50.0	24	16	10	0.05 x 0.05	0.13 x 0.13	0.16 x 0.16	0.32 x 0.32	0.64 x 0.64
18 x 18	1	18	14	43.8	36	25	16	0.05 x 0.05	0.14 x 0.14	0.18 x 0.18	0.36 x 0.36	0.72 x 0.72
20 x 20	1	22	18	45.0	44	31	20	0.06 x 0.06	0.16 x 0.16	0.20 x 0.20	0.40 x 0.40	0.80 x 0.80
22 x 22	1	30	20	40.0	60	43	28	0.07 x 0.07	0.18 x 0.18	0.22 x 0.22	0.44 x 0.44	0.88 x 0.88
24 x 24	1	36	24	40.0	72	52	34	0.07 x 0.07	0.19 x 0.19	0.24 x 0.24	0.48 x 0.48	0.96 x 0.96
26 x 26	1	44	28	38.9	88	64	42	0.08 x 0.08	0.21 x 0.21	0.26 x 0.26	0.52 x 0.52	1.04 x 1.04
32 x 32	4	62	36	36.7	124	91	60	0.10 x 0.10	0.26 x 0.26	0.32 x 0.32	0.64 x 0.64	1.28 x 1.28
36 x 36	4	86	42	32.8	172	127	84	0.11 x 0.11	0.29 x 0.29	0.36 x 0.36	0.72 x 0.72	1.44 x 1.44
40 x 40	4	114	48	29.6	228	169	112	0.12 x 0.12	0.32 x 0.32	0.40 x 0.40	0.80 x 0.80	1.60 x 1.60
44 x 44	4	144	56	28.0	288	214	142	0.13 x 0.13	0.35 x 0.35	0.44 x 0.44	0.88 x 0.88	1.76 x 1.76
48 x 48	4	174	68	28.1	348	259	172	0.14 x 0.14	0.38 x 0.38	0.48 x 0.48	0.96 x 0.96	1.92 x 1.92
52 x 52	4	204	84	29.2	408	304	202	0.16 x 0.16	0.42 x 0.42	0.52 x 0.52	1.04 x 1.04	2.08 x 2.08
64 x 64	16	280	112	28.6	560	418	277	0.19 x 0.19	0.51 x 0.51	0.64 x 0.64	1.28 x 1.28	2.56 x 2.56
72 x 72	16	368	144	28.1	736	550	365	0.22 x 0.22	0.58 x 0.58	0.72 x 0.72	1.44 x 1.44	2.88 x 2.88
80 x 80	16	456	192	29.6	912	682	453	0.24 x 0.24	0.64 x 0.64	0.80 x 0.80	1.60 x 1.60	3.20 x 3.20
88 x 88	16	576	224	28.0	1152	862	573	0.26 x 0.26	0.70 x 0.70	0.88 x 0.88	1.76 x 1.76	3.52 x 3.52
96 x 96	16	696	272	28.1	1392	1042	693	0.29 x 0.29	0.77 x 0.77	0.96 x 0.96	1.92 x 1.92	3.84 x 3.84
104 x 104	16	816	336	29.2	1632	1222	813	0.31 x 0.31	0.83 x 0.83	1.04 x 1.04	2.08 x 2.08	4.16 x 4.16
120 x 120	36	1050	408	28.0	2100	1573	1047	0.36 x 0.36	0.96 x 0.96	1.20 x 1.20	2.40 x 2.40	4.80 x 4.80
132 x 132	36	1304	496	27.6	2608	1954	1301	0.40 x 0.40	1.06 x 1.06	1.32 x 1.32	2.64 x 2.64	5.28 x 5.28
144 x 144	36	1558	620	28.5	3116	2335	1555	0.43 x 0.43	1.15 x 1.15	1.44 x 1.44	2.88 x 2.88	5.76 x 5.76
8 x 18	1	5	7	58.3	10	6	3	0.02 x 0.05	0.06 x 0.14	0.08 x 0.18	0.16 x 0.36	0.32 x 0.72
8 x 32	2	10	11	52.4	20	13	8	0.02 x 0.10	0.06 x 0.26	0.08 x 0.32	0.16 x 0.64	0.32 x 1.28
12 x 26	1	16	14	46.7	32	22	14	0.04 x 0.08	0.10 x 0.21	0.12 x 0.26	0.24 x 0.52	0.48 x 1.04
12 x 36	2	22	18	45.0	44	31	20	0.04 x 0.11	0.10 x 0.29	0.12 x 0.36	0.24 x 0.72	0.48 x 1.44
16 x 36	2	32	24	42.9	64	46	30	0.05 x 0.11	0.13 x 0.29	0.16 x 0.36	0.32 x 0.72	0.64 x 1.44
16 x 48	2	49	28	36.4	98	72	47	0.05 x 0.14	0.13 x 0.38	0.16 x 0.48	0.32 x 0.96	0.64 x 1.92

The "Information Capacity" value for alphanumeric mode can be larger when some numeric numbers are together and can be smaller when the upper and lower case alphabet are applied.

- Minimum recommended value is 1 cell size on all sides. Use zero if you do NOT want the quiet zone included in the calculations.

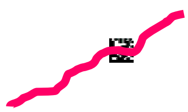
4.2.4.4 Data Matrix Cell Size by Environment

Decoding software examines each data cell to determine if it is filled or not (dark or light). If the grayscale average in the data cell is more than 50 percent, the software classifies the data cell as dark and assigns it a value of 1. If the grayscale average in the data cells is less than 50 percent, the cell is classified as light and assigned a value of 0.

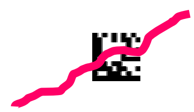
Smaller data cells are more likely to incur damage to more than 51 percent of the data cell, rendering the call unreadable. Symbols with large cell sizes are more likely to retain more than half of their structure when damaged and can be reconstructed by the decode software.

Consequently, cell sizes must be enlarged to overcome damage anticipated in harsh manufacturing, operational, and overhaul environments. Suggested data cell sizes by environment are illustrated in figure 11.

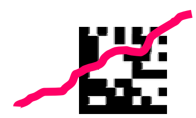
No Minimum size for Protected Environments	Minimum cell size for Moderate Damage	Minimum cell size for Harsh Environment
No cell size limit	0.010 inch (0.254 mm)	0.020 inch (0.508 mm) or larger



***Mark unreadable in unprotected environment**



***Mark readable using error correction**



***Less or no error correction needed**

NOTE: Cell sizes must be adjusted upwards as surface roughness increases.

Figure 11—Minimum Cell Sizes for Expected Use Environments

4.2.4.5 Marking Locations

Data Matrix decoding software, to be read successfully, requires a minimum of one data cell width of clear space (quiet zone) around the symbol. However, due to variations in surface finish, this requirement has been extended on NASA programs to 10 percent of the longest symbol side. In addition to this requirement, manufacturers often impose additional marking location restrictions within their drawings and/or specifications. These documents consider the effect that the markings have on the product's form, fit, and function. They also address symbol positioning as it relates to marking device clearance and reading during manufacture and after assembly. Unless otherwise directed, Data Matrix symbols shall not be applied in the following locations:

- High traffic areas
- Highly polished curved surfaces (RMS 0 to 8)
- Direct air streams (e.g., leading edge of wings, helicopter rotors, exposed portions of turbine blades, etc.)
- Near high-heat sources
- Sealing surfaces
- Wearing surfaces

In addition, operators must consider the effects of adjacent structures on the reader's illumination source. Fixed-station readers with movable light sources can generally be configured to successfully illuminate symbols placed in recesses or adjacent to protruding structures. These structures, however, can pose a challenge for hand-held readers with fixed-positioned light sources. Consequently, markings to be read in the field must be positioned for a sufficient amount of illumination to be projected to the symbol (see section 4.2.7, Mark Quality Verification).

4.2.5 Re-Marking Requirements

Additional part identification markings shall not be permitted without approval. This standard considers the material degradation caused by the application of a single human-readable and/or Data Matrix symbol applied using an intrusive marking method. Additional intrusive markings made to obliterate original markings and/or to add markings to correct errors or define changes may further reduce material properties beyond acceptability.

4.2.6 Protective Coatings

Intrusive markings applied to a surface that has been coated must be re-coated to prevent corrosion. Although metals often appear to be permanent, they are unstable in their operational environments and are susceptible to degradation by corrosion. This corrosion occurs when protective mechanisms have not been used or have been determined as no longer effective, leaving the metal vulnerable to hostile environments. Corrosion control is essential in the aerospace industry. Coatings are applied to marked surfaces to protect the marking and prevent corrosion.

A protective coating shall be:

a. Required when marks are subjected to wear, frequent handling, or environmental conditions that can damage the mark.

b. Clear so that all coatings remain visible or if opaque, use one of the read-through-paint methods as described in Appendix B.

c. Provide a protection level equal to or greater than the original protect finish. The coating shall not result in contamination later in the process and during ground, sub-orbital, and orbital operations. Matte finish coatings are preferable over glossy ones for readability. Typical coatings include, but are not limited to, the following.

4.2.6.1 Clear Anodize (MIL-A-8625E)

Anodizing is an electrolytic-oxidation process in which the metal surface, when anodic, is converted to a coating having desirable protective, decorative, or functional properties.

4.2.6.2 Lacquer (TT-L-50)

Lacquer is a coating based on thermoplastic film-forming material dissolved in organic solvent. The coating dries primarily by evaporation of the solvent. Typical lacquers include those based on lac, nitrocellulose, other cellulose derivatives, vinyl resins, acrylic resins, etc. Softer deposits are described as varnishes or gums.

4.2.6.3 Thin-Film Deposition

Thin-film deposition is a process that involves applying a clear metal film onto a substrate in a vacuum by metal evaporation techniques.

4.2.7 Mark Quality Verification

Data Matrix symbol markings shall be verified for quality in accordance with table 10.

Table 10—Mark Quality Verification Values

Grade	Action	*Symbol Contrast	Fixed Pattern Damage	Axial Non-Uniformity	Grid Non-Uniformity	Modulation	Unused Error Correction
4 (A)	Best	≥0.50	0%	≤0.06	≤0.38	≥0.50	≥0.62
3 (B)	Minimum at point of marking	≥0.40	≤9%	≤0.08	≤0.50	≥0.40	≥0.50
2 (C)	Minimum in use	≥0.30	≤13%	≤0.10	≤0.63	≥0.30	≥0.37
1 (D)	Fail - remark	≥0.20	≤17%	≤0.12	≤0.75	≥0.20	≥0.25
0 (F)	Worst	<0.20	>17%	>0.12	>0.75	<0.20	<0.25

NOTE: The information in table 10 is based on test results from external sources in partnership with NASA. Table 10 is a modified version of a table located in ISO/International Electrotechnical Commission (IEC) working draft (WD) 15415.

a. The overall grade shall be represented by the lowest of the values above.

b. On NASA programs, the minimum acceptable symbol grade at point of marking shall be “B.” Since some marks degrade slightly while in service, a grade of “C” is acceptable in use.

c. Marks failing to meet the required grade of “C” or better during use or following repair, refurbishment, or overhaul shall be dispositioned in accordance with section 4.2.5, Re-Marking Requirements (see figure 12).

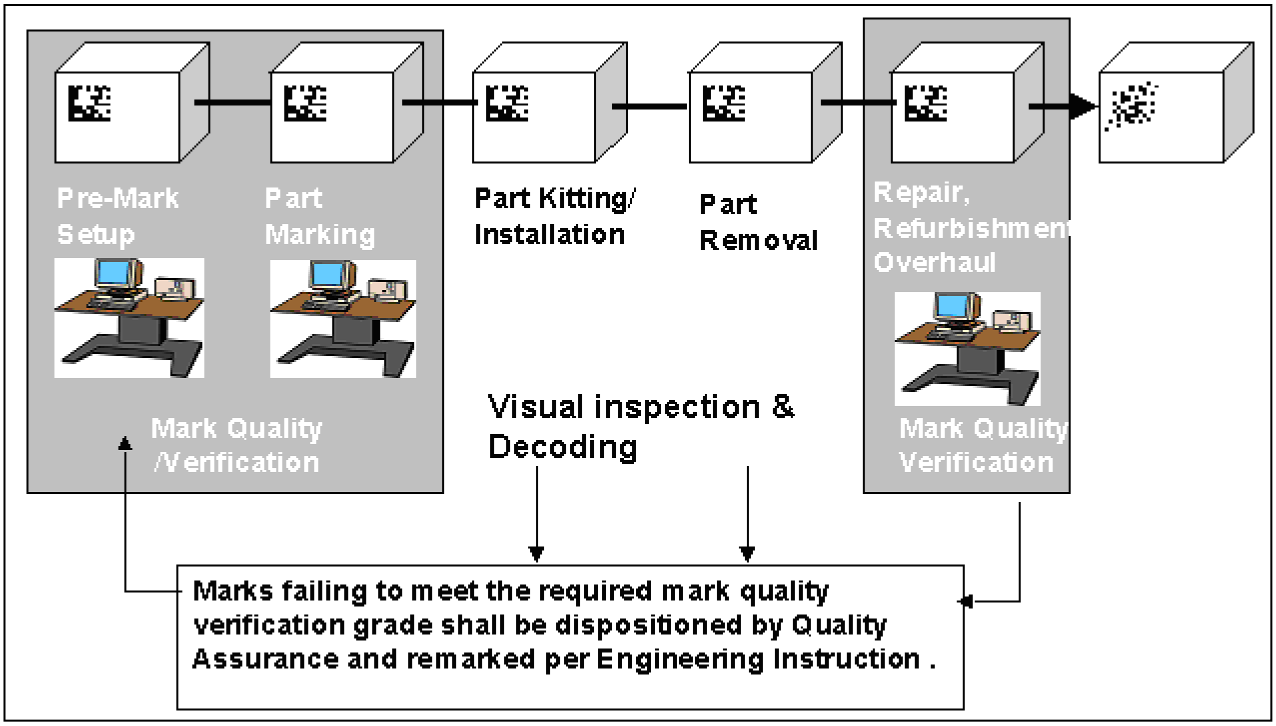


Figure 12—Mark Quality Verification Points

d. Mark quality verification equipment shall be configured to read the full range of symbol sizes reflected in table 1, and fitted with the lighting (direct, low-angle, and/or diffused illumination) required to eliminate glare or shadowing that may alter the appearance of the captured symbol image.

e. In-service reading should result in good reads. Bad-reads or no-reads resulting from bad marks shall be reported and dispositioned per section 4.2.5, Re-Marking Requirements. See section 3.2 for definitions.

4.2.8 Reading Requirements

The properties and limitations of the Data Matrix reader must always be considered. In general, this consideration leads to preferring a less reflective and smoother surface that is not deeply recessed or near protrusions. Data Matrix readers vary in their ability to read the Data Matrix on highly reflective or rough surfaces. The different reader types also operate with maximum effectiveness at varying distances from the surface containing the mark. Near-contact or touch readers may be hindered by protruding structures, or may cause inability to focus on the marks. Other readers that operate from a distance to the surface may have their illuminators shadowed when viewing marks are placed in recessed areas or are surrounded by protrusions. Therefore, the proper placement of the mark is a tradeoff between (1) the areas on the part that may be marked and (2) the areas on which the Data Matrix reader is effective.

4.2.9 Environmental, Health, and Safety

Environmental, health, and safety impacts in processes and materials shall be considered in employing identification marking methods and techniques.

4.2.9.1 Alternative Materials

Alternative, "environmentally friendly" materials, which contain low/no VOCs, shall be considered in determining the appropriate method/technique for each marking application. Many types of ink contain VOCs, such as methyl ethyl ketone, xylene, and toluene, which are principal components in atmospheric reactions that form ozone and other photochemical oxidants. Exposures to VOC-containing materials have health impacts, which include eye and respiratory irritation, headache, dizziness, memory impairment, neurotoxicity, and cancer.

5. GUIDANCE

5.1 Reference Documents

The documents cited in this section are listed for reference only. The specified technical requirements listed in the body of this document must be met whether or not the source document is listed in this section.

5.1.1 Government Documents

14-CRF (Parts 1-59)	FAA, DOT
FED-STD-595	Colors Used In Government Procurement (Fan Deck)
MIL-A-8625	Anodic Coatings For Aluminum And Aluminum Alloys
MIL-A-21380	Abrasive Materials, For Blasting
MIL-C-38736	Cleaning Compound, Solvent Mixtures (Metric)
MIL G-5634	Grain, Abrasive, Soft, for Carbon Removal
MIL-G-9954	Glass Beads, for Cleaning and Peening
MIL-H-6875	Heat Treatment of Steel Raw Materials
MIL-I-25135E	Inspection Materials, Penetrants
MIL-P-85891	Plastic Media, for Removal of Organic Coatings
MIL-STD-10A	Surface Roughness Waviness and Lay
MIL-STD-869	Flame Spraying
MIL-STD-871	Electro-Chemical Stripping of Inorganic Finishes
MIL-STD-130	Identification Marking of U.S. Military Property
MIL-STD-1504	Abrasive Blasting
MIL-STD-6866	Inspection, Liquid Penetrant
NASA-HDBK-6003	Application of Data Matrix Identification Symbols to Aerospace Parts Using Direct Part Marking Methods/Techniques

Copies of these documents are available online at http://assist.daps.dla.mil/quicksearch/ or www.dsp.dla.mil or from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.

5.1.2 Non-Government Documents

	AIM International Symbology Specification – Data Matrix
	AIM USA Uniform Symbology Specification for Data Matrix
	American National Standard X3.182 Bar Code Print Quality Guidelines
AIAG B4	Parts Identification and Tracking Application Standards – Pending
AMS-S-13165	Shot Peening of Metal Parts
ANSI T1.220	Information Interchange - Coded Representation of the North American Telecommunications Industry Manufacturers, Suppliers and Related Service Companies
ASM, Volume 5	ASM Handbook, Surface Engineering
ASME B46.1-02	Surface Texture (Surface Roughness, Waviness, and Lay)
ASTM B-117-03	Standard Practice for Operating Salt Spray (Fog) Apparatus
ASTM D-522-93	Standard Test Methods for Mandrel Bend Test of Attached Organic Coatings
ASTM D-673-93	Standard Test Method for Mar Resistance of Plastics
ASTM D-870-02	Standard Practice for Testing Water Resistance of Coatings Using Water Immersion
ASTM D-1003-02	Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics Transparency
ASTM D-1308	Standard Test Method for Effect of Household Chemicals on Clear and Pigmented Organic Finishes (with addition of sulfuric acid testing)
ASTM D-2247-02	Standard Practice for Testing Water Resistance of Coatings in 100% Relative Humidity
ASTM D-2485-91 (2000)	Standard Test Methods for Evaluating Coatings For High Temperature Service
ASTM D-2794-93 (2004)	Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)
ASTM D-3359-02	Standard Test Methods for Measuring Adhesion by Tape Test
ASTM D-3363-00	Standard Test Method for Film Hardness by Pencil Test
ASTM D-3794-94	Standard Guide for Testing Coil Coatings
ASTM D-4060-01	Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser
ASTM E-96-95	Test Methods for E96-95 Water Vapor Transmission of Materials, Standard
ASTM E-96-01el	Standard Test Methods for E96-95 Water Vapor Transmission of Materials
ASTM G-23-96	Standard Practice for Operating Light-Exposure Apparatus

	(Carbon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials
ASTM G-26-95	Standard Practice for Operating Light-Exposure Apparatus (Xenon-Arc Type) With and Without Water for Exposure of Nonmetallic Materials
ASTM G-53-96	Standard Practice for Operating Light- and Water-Exposure Apparatus (Fluorescent UV-Condensation Type) for Exposure of Nonmetallic Materials
ASTM G-120	Standard Practice for Determination of Soluble Residual Contamination in Materials and Components by Soxhlet Extraction
ASTM G-131-96	Standard Practice for Cleaning of Materials and Components by Ultrasonic Techniques
ASTM G-144-1996	Standard Test Method for Determination of Residual Contamination of Materials and Components by Total Carbon Analysis Using a High Temperature Combustion Analyzer
ASTM G-154	Standard Practice for Fluorescent for UV Exposure of Nonmetallic Materials
ASTM G-155	Standard Practice for Operating Xenon-Arc Light Apparatus for Exposure of Non-metallic Materials
ATA SPEC-2000	E-Business Specifications for Materials Management, Chapter 9, Bar Coding
EIA-624	Product Package Bar Code Label Standard for Non-Retail Applications
EIA/CEA-706	Component Marking Standard (Data Matrix)
EIA/CEA-802	Product Marking Standard

Copies of these documents are available from Consumer Electronics Association (CEA), 2500 Wilson Blvd., Arlington, VA 22201-3834, http://www.ce.org/.

EIA SP-3497	Component Product Marking Standard (Data Matrix)
ISO/IEC 15415	2-D Symbol Print Quality – Pending
ISO/IEC 16022	Information Technology International Symbology Specification Data Matrix
SAE-AMS-2806	Identification, Bars, Wire, Mechanical Tubing And Extrusions, Carbon And Alloy Steels And Corrosion And Heat Resistant Steels And Alloys
SAE-AMS-2807	Identification, Carbon And Low-Alloy Steels, Corrosion And Heat Resistant Steels And Alloys Sheet, Strip, Plate, And Aircraft Tubing
SAE-AMS-STD-184	Identification Marking of Aluminum, Magnesium, And Titanium

SAE-AMS-STD-185	Identification Marking of Copper And Copper Base Alloy Mill Products

Copies of the SAE documents are available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, or http://www.sae.org/servlets/index

SEMI T7-0997	Specification for the Back Surface of Double-Sided Polished Wafers with a 2-D Matrix Code Symbol
SEMI T2-98	Specification for Marking of Wafers with 2-D Matrix Code Symbol
SEMI T8-0698	Specification for Marking of Glass Flat Panel Display Substrates with A 2-D Matrix Code Symbol
SEMI T9-2000	Specification for Marking Metal Lead-Frame Strips With 2-D Matrix Code Symbols
SEMI 2999	Specification for the Assessment of 2D Data Matrix Direct Mark Quality (Draft Document)
TT-C-490	Chemical Conversion Coatings and Pretreatments for Ferrous Surfaces (Base for Organic Coatings)
TT-L-50	Lacquer, Nitrocellulose, Acrylic and Acrylic Butyrate, Aerosal (In Pressurized Dispensers)
	Uniform Code Council (UCC) Standards – (To apply for UCC Manufacturer Identification Codes contact Uniform Code Council, 8163 Old Yankee road, Suite J, Dayton, OH 45458, telephone 513 435-3870)
	Uniform Symbology Specification for Data Matrix – (available from AIM USA, 634 Alpha Drive, Pittsburg, PA 15238-2802, telephone 412 963-8588)
UPS S28-1	Identification/Codification Standards (Data Matrix and PDF417)

5.2 Key Word Listing

Data matrix
Direct part marking
License tag number
Machine-readable symbol
Part identification
Part marking
Protective coating

5.3 Background

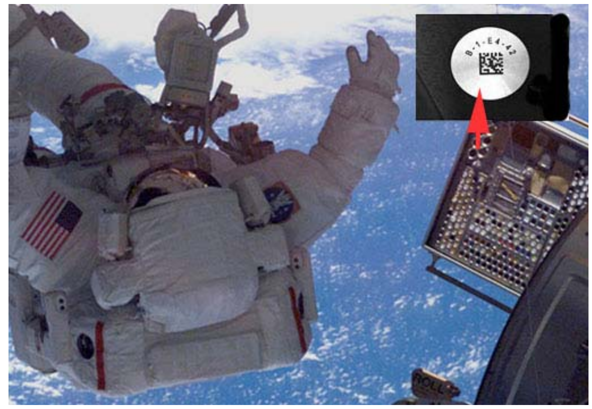
Recognizing that manual data collection and keyed data entry were inefficient and error prone, NASA adopted bar code technology in the mid-1980s to upgrade its operations. It soon became apparent that collecting the identity of the part from a symbol marked directly on it would be optimal. Bar codes were determined not to be suitable for DPM. NASA established a team to work with industry to develop and test machine-readable two-dimensional (2-D) symbols designed to be applied to non-paper substrates. This 5-year effort resulted in the selection of the Data Matrix symbol for use in NASA applications, and provided proof that 2-D symbols are reliable and can be applied to most aerospace materials without impacting performance. NASA findings spurred additional testing by DoD and private industry, resulting in selection of the Data Matrix symbol for parts marking by AIM and ANSI. Additional part-marking standards quickly followed as the automotive, electronics, pharmaceutical, and aircraft industries adopted the symbol.

These industries, including NASA, have relied heavily on the use of mold, cast, or forge; engraving, electrical arc pencil, electrical-chemical marking, embossing; hot stamp, rubber ink stamp, stencil, and silk screen; and vibration-etch for part identification marking. These marking methods, originally designed to apply human-readable markings, do not provide the fidelity needed to successfully mark high-density machine-readable symbols. Their manual operations also added to the number of data transposition errors associated with paper-based manufacturing systems.

Understanding these weaknesses, the parts identification industry began to refine existing marking methods so they could be utilized to apply 2-D symbols. The manual metal stamp, vibro-etch, and embossing technique methods were replaced by dot peen machines. Automated micro-profilers were designed to replace the manual cutting wheel used to produce paint stencils. Photo stencils and thermal printing materials were developed to replace the direct-impact electro-chemical marking stencils. Ink-jet and adhesive-dispensing machines were built to replace rubber stamps. Laser marking systems were designed to replace the electric-arc etch and hot-stamp processes. These methods and other new marking processes have been incorporated into this standard.

APPENDIX A

MISSE PROGRAM INFORMATION



MISSE was launched into LEO on August 9, 2001, at 5:38 PM on the Space Shuttle Discovery (Mission STS-105). The experiment was attached to the exterior of the International Space Station by Patrick G. Forrester as part of an extravehicular activity (EVA), commonly called a spacewalk.

Included in the experiment trays are number disks with typical spacecraft materials marked with Data Matrix symbols, using a wide range of marking processes. The trays are oriented to expose the disks to LEO environments. These include extreme levels of ultraviolet radiation, atomic oxygen, hard vacuum, and contamination, all of which have a strong degrading effect on some types of materials. Photographs of the markings taken after one year of exposure verify that the new processes are working. Data obtained after retrieval is to be incorporated into table 7 of this standard.

Qualifying materials for long-term use in space is made especially challenging because this unique environment is so difficult to simulate in a laboratory. With MISSE, no laboratory is needed. On-orbit testing is accomplished by flying the materials outside the International Space Station for a period of one to three years. The marked Data Matrix disks are installed in two Passive Experiment Containers (PECs). The two containers are scheduled to be retrieved during the second Space Shuttle mission following return to flight, and are to be analyzed to determine the preferred marking sizes and processes used to apply part identification markings on future reusable spacecraft. Placeholders for this data have been incorporated into this revision of the standard.

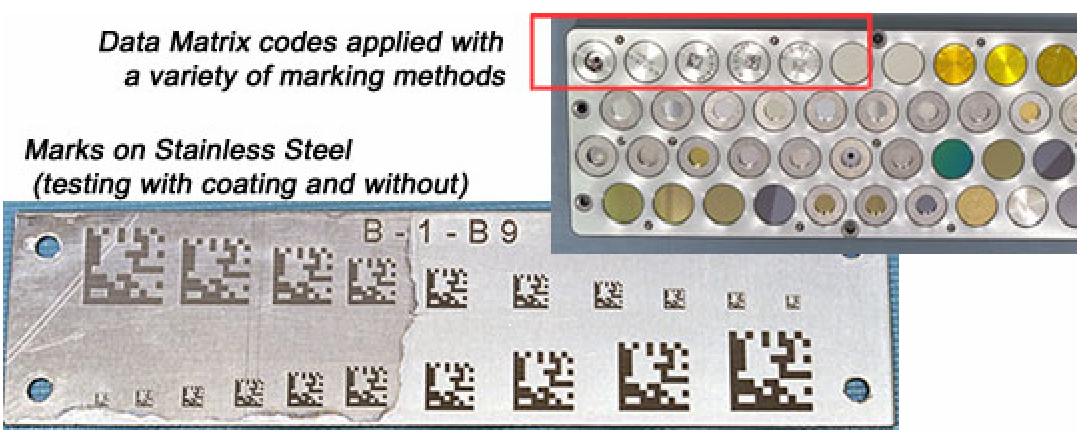


Table 11—MISSE Marking Sample Data

Specimen Number	Base Material	Marking Method	Marking Material	Encoded Info.	Planned Orbit Duration	Color of Mark	Initial Grade	Post Flight Grade	Marking Equipment
B-1-E3-27	Glass	LIVD	Brass	Line Pattern	1 yr.	Dark Brown	Good Contrast		Rofin-Sinar Nd:YAG Laser
B-1-E3-28	Glass	LIVD	Tin	Line Pattern	1 yr.	Black	Good Contrast		Rofin-Sinar Nd:YAG Laser
B-1-E3-29	Glass	Laser Bonding	Cerdec RD-6005	Line Pattern	1 yr.	Gray-Black	Excellent Contrast		Rofin-Sinar Nd:YAG Laser
B-1-E3-30	Glass	VAVD	Copper	Line Pattern	1 yr.	Dark Gray	Good Contrast		Rofin-Sinar Nd:YAG Laser
B-1-E3-31	Glass	LIVD	Tin	B1E331	1 yr.	Black	A		Rofin-Sinar Nd:YAG Laser
B-1-E10-03	Glass	LIVD	Brass	Line Pattern	1 yr.	Dark Brown	Good Contrast		Rofin-Sinar Nd:YAG Laser
B-1-E10-04	Glass	LIVD	Tin	Line Pattern	1 yr.	Black	Good Contrast		Rofin-Sinar Nd:YAG Laser
B-1-E10-05	Glass	Laser Bonding	Cerdec RD-6005	Line Pattern	1 yr.	Gray-Black	Excellent Contrast		Rofin-Sinar Nd:YAG Laser
B-1-E10-06	Glass	VAVD	Copper	Line Pattern	1 yr.	Dark Gray	Good Contrast		Rofin-Sinar Nd:YAG Laser
B-1-E10-07	Glass	LIVD	Brass	B1E107	1 yr.	Dark Brown	A		Rofin-Sinar Nd:YAG Laser

Table 11—MISSE Marking Sample Data (continued)

Specimen Number	Base Material	Marking Method	Marking Material	Encoded Info.	Planned Orbit Duration	Color of Mark	Initial Grade	Post Flight Grade	Marking Equipment
B-1-E4-42	Aluminum	Laser Bonding	Cerdec RD-6000	B1E442	1 yr.	Black	A		Rofin-Sinar Nd:YAG Laser
B-1-E4-43	Glass	Laser Bonding	Cercec RD-6005	B1E443	1 yr.	Black	A		Rofin-Sinar Nd:YAG Laser
B-1-E4-44	Aluminum	VAVD	Copper	B1E444	1 yr.	White	A		Rofin-Sinar Nd:YAG Laser
B-1-E4-45	Aluminum	GALE	Argon Gas	CiMatx	1 yr.	Dark Gray	A		LMT Diode-Pumped Laser
B-1-E4-46	Aluminum	Chemical Etching	SCE-4	B1E446	1 yr.	Gray	A		Electo-Chem Etch Machine
B-2-E16-42	Aluminum	Dot Peen	N/A	2E1642	3 yrs.	White	A		Telesis TMP 6000 Pinstamp
B-2-E16-43	Aluminum	Laser Etching	N/A	2E1643	3 yrs.	Dark Gray	A		Rofin-Sinar Nd:YAG Laser
B-2-E16-44	Aluminum	LISI	Metallic Powders	2E1644	3 yrs.	Dark Gray	A		Rofin-Sinar Nd:YAG Laser
B-2-E16-45	Aluminum	Laser Shot Peening	N/A	2E1645	3 yrs.	White	B		Neodymium-Doped glass Laser
B-2-E16-46	7980 Glass (Corning)	LIVD	Tin	2E1646	3 yrs.	Black	A		Rofin-Sinar Nd:YAG Laser
B-1-B9	Aluminum Plate	Laser Etching	N/A	123456	3 yrs.	Gray	A		Rofin-Sinar Nd:YAG Laser

APPENDIX B

EXAMPLES OF SENSOR-BASED READERS

Magneto-Optic Reader: Contact reader. The imager shown to the right produces images of magnetic fields emitted from the magnetic material used in the marking medium that forms the desired Data Matrix pattern.

Ultrasound Reader: Contact reader. The imager detects differences in acoustic impedance (density) or variations in the reflected acoustic pattern (surface texture), or both.

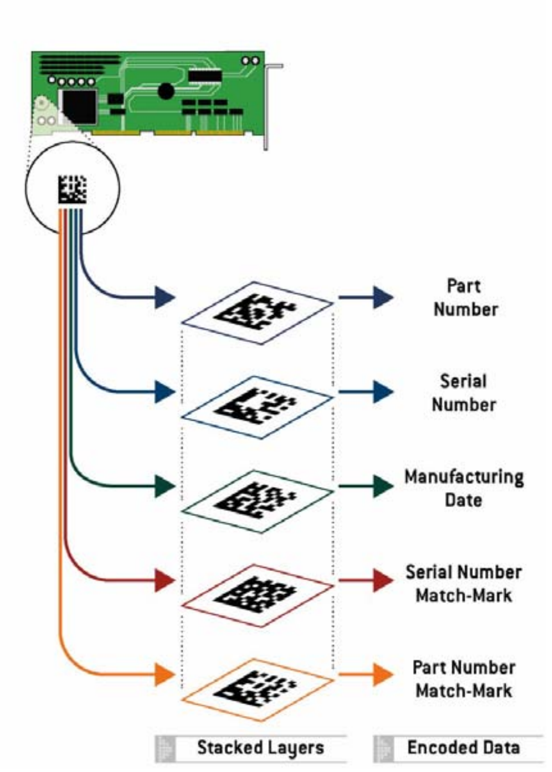
Capacitance Reader: Contact reader. The imager detects resistance to current flow through a material.

Micro-Impulse Radar Reader: Non-contact reader. The imager detects differences in radio-signal return times or strength within a predetermined time interval.

Thermal or Infrared Reader: Non-contact reader. Marking materials must provide an emissivity or reflectance level that differs from that of the host product.

X-Ray Reader: Non-contact reader. The imager detects areas of greater density by passing a beam through the product to expose an underlying x-ray sensitive film.

Stacked Data Matrix Codes: Mixed contact and non-contact.



Sensor readers provide the capability to distinguish markings that are hidden for aesthetic or security reasons. Each sensor type detects materials with specific characteristics, and in some cases, can locate these materials at specific depths (making them suited for the detection of stacked symbols). This process eventually leads to placing large amounts of data in limited marking areas. The stacked symbol in the adjacent figure illustrates that.

Identification data encoded in matrix symbols would be marked on layers, and the layers would be stacked.

Each layer would be marked with a substance that is sensed by a different method.

Layers would represent identifying designations, such as part number or serial number, but recognizable only to a specific scanner.

Applications include those where security is needed or for anti-counterfeiting of identification marks precluded by complexity.

APPENDIX C

X-RAY FLUORESCENCE DETECTION SYSTEMS

C.1 Identification

Today, part identification technologies that are used on aircraft, aerospace, or military parts are primarily the human-readable designations marked where space is available on the substrate that is topographically suitable for marking. Those parts that lack the substrate space or topographical suitability usually do not have their identity marked directly on them. Their identity is marked on the bags in which they are packaged for protection or the containers that are used for their shipping. Marking bags and containers with labels provide the opportunity to use bar codes and collect part identity accurately one time. Once these parts are removed from their packaging, traceability is lost because their identity is separate from them and automatic data collection is not possible. At this point, the nonidentity of these parts causes them to become usage items, having to be scrapped the first time they are serviced, since they have no verifiable link to a database for tracking.

For example, under FAA regulations, all aircraft parts manufactured without FAA approval are unapproved parts. This generic classification includes counterfeit parts, stolen parts, production overruns sold without authorization, parts exceeding their time limits, approved parts improperly returned to service, fraudulently marked parts, or parts that have no traceability. These unapproved parts are difficult, if not impossible, to identify and currently represent a significant percentage of existing DoD inventories. NASA experiences this problem to a much lesser degree, but since the FAA, DoD, and NASA have so many common suppliers, NASA is susceptible to part identification and verification problems.

Direct part marking very small Data Matrix symbols remedies the situation for many of these parts and provides a link to their pedigree throughout their life cycle. Where nonidentity currently exists, resulting in low-quality or unapproved parts, the transition to direct part marking of Data Matrix symbols eliminates human error and provides a basis for part verification.

There are many parts that still cannot be marked with Data Matrix symbols due to stress considerations, size, or other factors. Small damping seals, thin diaphragms, and some polymers are examples of delicate or difficult parts to mark. For these parts, a chemical taggant known as Nanocode™ has been devised that can serve as a Data Matrix or bar code, representing a portion of the part identity linked to the pedigree database. The Nanocode™ is sprayed on, built in, or contained in a coating, and is detected by x-ray fluorescence. The x-ray fluorescence scanner and detector used to read the Nanocodes™ are shown in figure 13. These devices can evaluate chemical compositions in a matter of seconds. The XRF technology, therefore, provides a reliable solution to the identification of parts that are otherwise difficult to mark with Data Matrix symbols. This solution has the potential of preventing reusable parts from being discarded due to absence of adequate identification.

Figure 13—Hand-Held Scanner and Detector

Nanocode™ using x-ray fluorescence works by devising a chemical taggant of known composition. Nanocodes™ are mixtures of known chemicals at known concentrations that are integrated onto an object for identification or authentication.

When the x-ray fluorescence scanner is activated, some of the x-rays from the instrument strike and eject electrons from the inner shell of the atoms in the target. Next, an electron from an outer shell fills the space in the inner shell. An x-ray photon is released and hits the detector. This photon's energy is unique to the element it came from, e.g., K-shell Aluminum at 1.87 keV).
See figure 14.

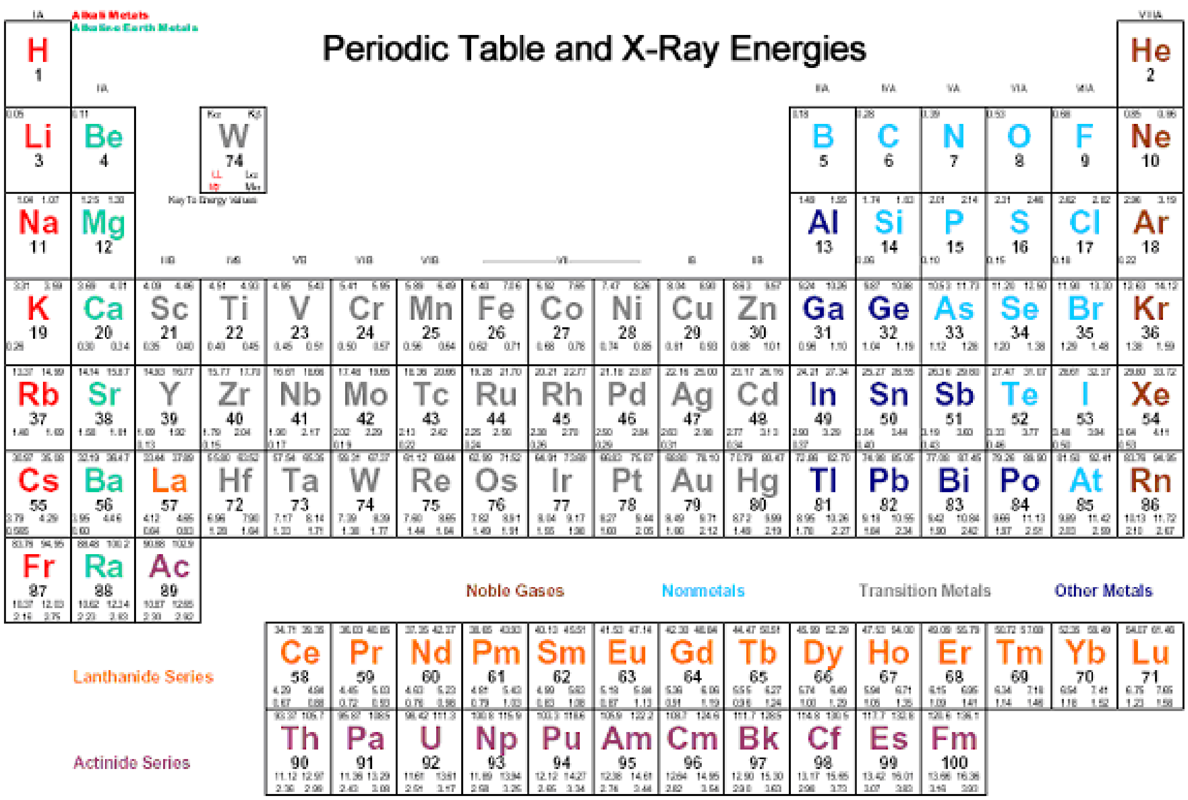


Figure 14—Periodic Table and X-Ray Energies

Each element has its own signature energy for K and L electron shells. The Nanocode™ is decoded by software contained in the detection device and communicated to a database in the same manner as a Data Matrix symbol or bar code. Each element represents a different letter or number in the ASCII Table, the arrangement of which relates to the identity of a part. See figures 15 and 16.

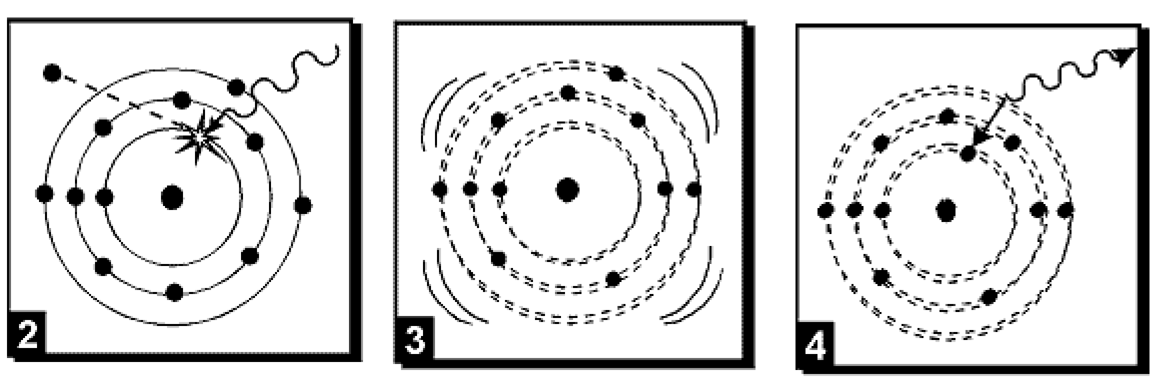


Figure 15—X-Ray Energies

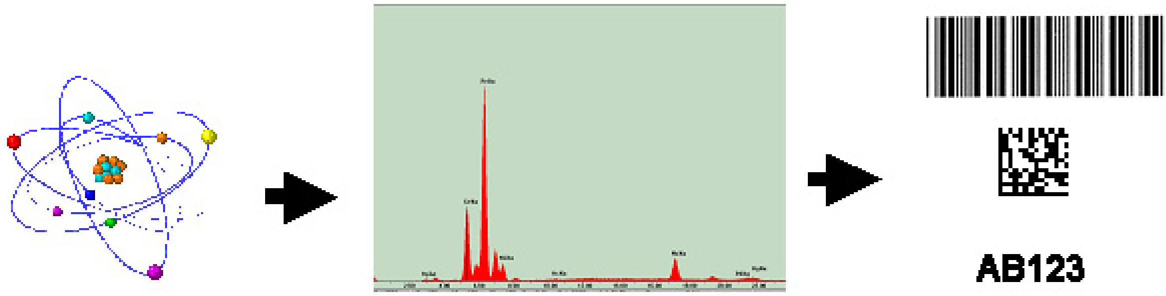


Figure 16—X-Ray Energies

C.2 Authentication

Authentication is the other useful application of XRF tagging. "Authentication" is defined as confirming that a part is genuine.

Today, there is no way to authenticate a part by scanning a Data Matrix symbol or bar code, both being fairly generic in design and application, and easily counterfeited. Bar codes and other labels that are marked on packaging or containers can be replaced by other stick-on labels and can easily identify unapproved parts incorrectly. Symbols, such as Data Matrix, that are marked on parts can also be duplicated on unapproved parts until database safeguards prohibit their use. Currently, both labels and direct marks can only be used for routine part identification.

Nanocode™ elemental tagging can be used in combination with the other methods of part identification to form an authentication system for part identity. Working in conjunction with labels and direct marks, the intrinsically indestructible Nanocodes™ serve as "secret bar codes" inside the part that repeat selected identity information contained in the other marks. See figure 17.

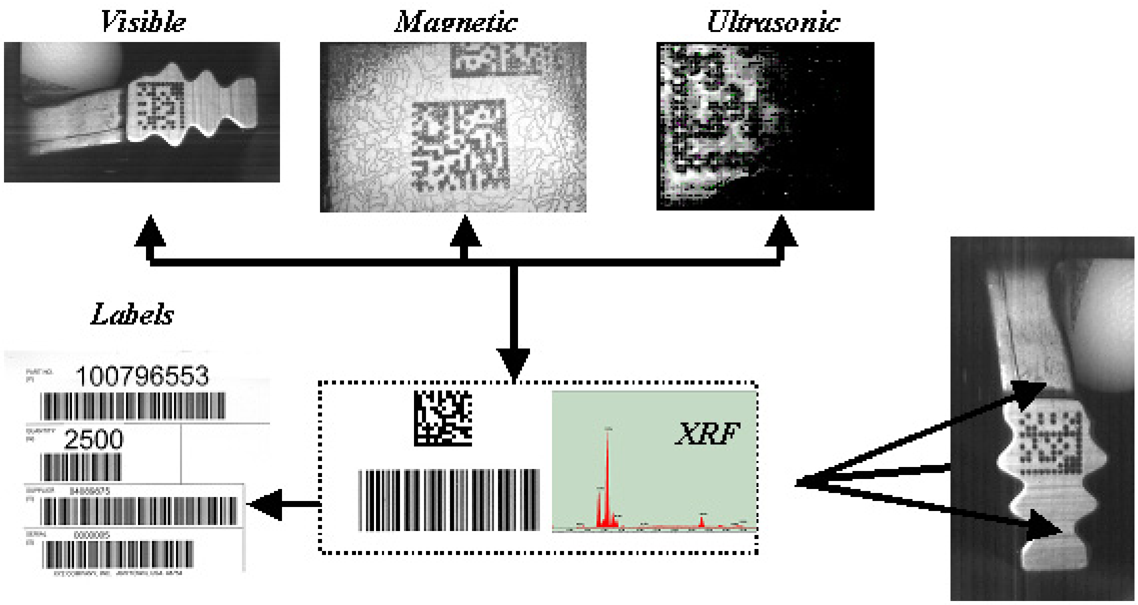


Figure 17—Authentication

This method is especially useful in commercial anti-counterfeiting efforts. It is also an extremely reliable factor in liability cases where the "secret bar code" is applied at the point of manufacture. When liability cases occur that possibly involve counterfeit parts, authentication technologies such as Nanocode™ firmly establish whether or not the part that failed was made by a given manufacturer. NASA benefits from these part-authentication methods for acceptance, use, and overhaul.